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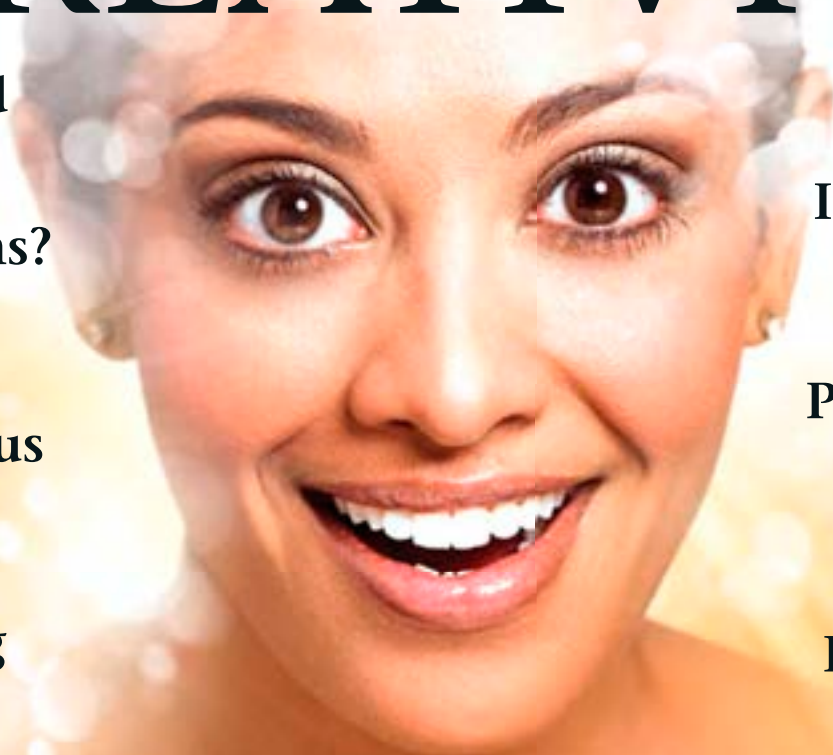
THE MAD SCIENCE OF CREATIVITY



When Did Ingenuity First Arise in Humans?

So You Want to Be a Genius

The Trick to Lucid Dreaming

How Cities Fire the Imagination

Why Creative People Often Seem Weird

The Serious Need for Imaginative Play

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UNLEASHING THE CREATIVE MIND

My parents thought I would make a good doctor or engineer. I excelled at science and math, after all. Instead I chose to pursue journalism, even though it seemed better suited for a "creative person" than for me. I had a passion for writing but not necessarily a flair, and my early efforts were not pretty. Fortunately, as this special edition shows, creativity is not just something you're born with. Most of us have more of it than we realize.

Some people, of course, have a creative edge from an early age. In "Predicting Artistic Brilliance," on page 12, Jennifer E. Drake and Ellen Winner write about a two-year-old who would work meticulously for days on a single drawing and about another child who drew astonishingly realistic dinosaurs by age six. These children have what the authors call "a rage to master."

What makes some people more creative than others? In "The Unleashed Mind," on page 28, Shelley Carson writes that genetic variations may make some people's brain more open to thoughts, sensations and behaviors that don't make it past the average person's mental filters. These same variations may also explain why many highly creative people seem eccentric at times—or even suffer from mental illness.

Despite these genetic variations, "nurture may still account for the lion's share of genius," writes Dean Keith Simonton in "The Science of Genius," starting on page 20. Practice, training and exposure to unfamiliar ideas and experiences play essential roles in shaping creativity. Even something as simple as living in a big city promotes creativity because close contact with other humans breeds new ideas, explains Edward Glaeser in "Engines of Innovation," on page 102.

Dreams and imaginative play can also nurture creativity. Dreaming may allow ideas to incubate during sleep, leading to inspiration during waking hours, writes Deirdre Barrett in "Answers while You Sleep," on page 58. Daydreaming can likewise fire up neurons that give you access to ideas and solutions hovering below the surface of your consciousness, as Josie Glausiusz writes in "Living in an Imaginary World," on page 70. Stimulating the brain with a weak electric current to make the left hemisphere less dominant may even boost creative thinking, according to Allan W. Snyder et al. in "Switching on Creativity," on page 108. A panel of experts reveals other powerful techniques for cultivating originality in "Let Your Creativity Soar," on page 94.

As it turns out, creativity is just as important in medicine and engineering as it is in journalism. In "Your Fertile Brain at Work," beginning on page 86, Evangelia G. Chrysikou explains how innovation can elevate the careers of chefs, university presidents, psychotherapists, police detectives, teachers, engineers, architects, attorneys and surgeons. We hope this special issue will help you unleash your own creative self.

Dawn Stover
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THE ORIGINS OF CREATIVITY

New evidence of ancient ingenuity forces scientists to reconsider when our ancestors started thinking outside the box

By Heather Pringle

Illustration by David Palumbo

FAST FACTS

CREATIVE CAPACITY

❶ Scientists long thought that early humans were stuck in a creative rut until some 40,000 years ago, when their powers of innovation seemed to explode.

❷ But archaeological discoveries made in recent years have shown that our ancestors had flashes of brilliance far earlier than that.

❸ These findings indicate that the human capacity for innovation emerged over hundreds of thousands of years, driven by both biological and social factors.

Unsigned and undated, inventory number 779 hangs behind thick glass in the Louvre's brilliantly lit Salle des États. A few minutes after the stroke of nine each morning, except for Tuesdays when the museum remains closed, Parisians and tourists, art lovers and curiosity seekers begin flooding into the room. As their hushed voices blend into a steady hivelike hum, some crane for the best view; others stretch their arms urgently upward, clicking cell-phone cameras. Most, however, tilt forward, a look of rapt wonder on their faces, as they study one of humanity's most celebrated creations: the *Mona Lisa*, by Leonardo da Vinci.

Completed in the early 16th century, the *Mona Lisa* possesses a

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mysterious, otherworldly beauty quite unlike any portrait that came before it. To produce such a painting, Leonardo developed a new artistic technique he called *sfumato,* or "smoke." Over a period of several years he applied translucent glazes in delicate films—some no more than the thickness of a red blood cell—to the painting, most likely with the sensitive tip of his finger. Gradually stacking as many as 30 of these films one on top of another, Leonardo subtly softened lines and color gradations until it seemed as if the entire composition lay behind a veil of smoke.

The *Mona Lisa* is clearly a work of inventive genius, a masterpiece that stands alongside the music of Mozart, the jewels of Fabergé, the choreography of Martha Graham, and other such classics. But these renowned works are only the grandest manifestations of a trait that has long seemed part of our human hardwiring: the ability to create something new and desirable, the knack of continually improving designs and technologies—from the latest zero-emissions cars made in Japan to the sleekly engineered Falcon 9 rockets from SpaceX. Modern humans, says Christopher S. Henshilwood, an archaeologist at the Universities of Bergen in Norway and the Witwatersrand, Johannesburg, in South Africa, "are inventors of note. We advance and experiment with technology constantly."

Just how we came by this seemingly infinite capacity to create is the subject of intense scientific study: we were not always such whirlwinds of invention. Although our human lineage emerged in Africa around six million years ago, early family members left behind little visible record of innovation for nearly 3.4 million years, suggesting that they obtained plant and animal foods by hand, with tools such as digging or jabbing sticks that did not preserve. Then, at some point, wandering hominins started flaking water-worn cobblestones with hammerstones to produce cutting tools. That was an act of astonishing ingenuity, to be sure, but a long plateau followed—during which very little seems to have happened on the creativity front. Our early ancestors apparently knapped the same style of handheld, multipurpose hand ax for 1.6 million years, with only minor tweaks to the template. "Those tools are really kind of stereotypical," says Sally McBrearty, an archaeologist at the University of Connecticut.

So when did the human mind begin churning with new ideas for technology and art? Until recently, most researchers pointed to the start of the Upper Paleolithic period 40,000 years ago, when *Homo sapiens* embarked on what seemed a sudden, wondrous invention spree in Europe: fashioning shell-bead necklaces, adorning cave walls with geometric signs and paintings of Ice Age animals, and carving and knapping a wide variety of new stone and bone tools. The finds prompted a popular theory proposing that a random genetic mutation at around that time had spurred a sudden leap in human cognition, igniting a creative "big bang."

New evidence, however, has cast grave doubt on the mutation theory. Over the past decade or so archaeologists have uncovered far older evidence of art and advanced technology, suggesting that the human capacity to cook up new ideas evolved much earlier than previously thought—even before the emergence of *H. sapiens* 200,000 years ago. Yet although our capacity for creativity sparked early on, it then smoldered for millennia before finally catching fire in our species in Africa and Europe. The evidence seems to indicate that our power of innovation did not burst into existence fully formed late in our evolutionary history but rather gained steam over hundreds of thousands of years, fueled by a complex mix of biological and social factors.

Exactly when did humankind begin thinking outside the box, and what factors converged to ultimately fan our brilliant creative fire? Understanding this scenario requires following a detective story composed of several strands of evidence, starting with the one showing that the biological roots of our creativity date back much further than scientists once thought.

Mother of Invention

Archaeologists have long viewed the use of symbols as the single most important indicator of modern human cognition, in large part because it attests to a capacity for language—a hallmark human trait. Thus, the geometric signs and the spectacular cave art of the Upper Paleolithic clearly signal the presence of people who thought as we do. But more recently, experts have begun searching for hints of other kinds of modern behavior and its antecedents in the archaeological record—and coming up with fascinating clues.

Archaeologist Lyn Wadley of the University of the Witwatersrand, Johannesburg, has spent much of her career studying ancient cognition, research that led her in the 1990s to open excavations at Sibudu Cave, some 40 kilometers north of Durban, South Africa. At that same site, about five years ago, she and her team discovered a layer of strange, white, fibrous plant material there. To Wadley, the pale, brittle mash looked like ancient bedding—rushes and other plants that later people often scattered on the ground for sitting and sleeping on. But the layer could also have formed from wind-borne leaf litter. The only way to tell one from the other was to encase the entire layer in a protective plaster jacket and take it back to the laboratory. "It took us three weeks to make all that plaster," Wadley recounts, "and I was really grumpy the whole time. I kept wondering, 'Am I wasting three weeks in the field?'"

But Wadley's gamble paid off richly. In 2011 she and her colleagues reported in

ALTHOUGH OUR CAPACITY FOR CREATIVITY SPARKED EARLY ON, IT THEN SMOLDERED FOR MILLENNIA **BEFORE FINALLY CATCHING FIRE IN OUR SPECIES** IN AFRICA AND EUROPE.

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FERMENTING GENIUS

Surprisingly early examples of technological and artistic inventiveness indicate that human creativity simmered for hundreds of thousands of years before reaching a boil around 90,000 to 60,000 years ago in Africa and 40,000 years ago in Europe. Social factors, including an increase in population size, seem likely to have amplified our ancestors' powers of innovation, both by improving the odds that someone in the group would come up with a breakthrough technology and by fostering connectedness between groups that allowed them to exchange ideas. This timeline charts the earliest known evidence of key innovations leading up to the cultural boiling point.

3.4 million years ago
Cut-marked animal bones from Dikika, Ethiopia

2.6 million years ago
Flaked stone tools from Gona, Ethiopia

1.76 million years ago
Bifacial stone tool from Turkana, Kenya

1 million years ago
Burned bone and plant material indicative of controlled fire from Wonderwerk Cave, South Africa

500,000 years ago
Composite tools—in the form of stone points that would have been affixed to wood shafts—from Kathu Pan 1, South Africa

164,000 years ago
Heat-treated stone tools from Pinnacle Point, South Africa

71,000 years ago
Projectile points from Pinnacle Point, South Africa

100,000–75,000 years ago
Engraved ocher (iron oxide) from Blombos Cave, South Africa

77,000 years ago
Insect-repellent bedding from Sibudu Cave, South Africa

40,000–30,000 years ago
Sewing needles from Kostenki, Russia

43,000–42,000 years ago
Musical instrument (flute) from Hohle Fels Cave, Germany

41,000–37,000 years ago
Cave art, including hand stencils, from El Castillo, Spain

40,000–35,000 years ago
Figurative art: the Venus of Hohle Fels, Germany

IN ORDER OF TIMELINE: COURTESY OF P. J. TEXIER, © MPK/WTAP; COURTESY OF JAYNE WILKINS *University of Toronto*; COURTESY OF CHRISTOPHER S. HENSHILWOOD *Universities of Bergen and the Witwatersrand, Johannesburg*; COURTESY OF TOVE RUTH SMITH AND SIMEN OESTMO; SASCHA SCHUERMANN *Getty Images*; COURTESY OF D. AND G. VON PETZINGER; MICHAEL LATZ *AP Photo*

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1

COURTESY OF LYN WADLEY *University of the Witwatersrand, Johannesburg*

Science that Sibudu's occupants selected leaves from just one of many woody species in the area to make bedding 77,000 years ago—nearly 50,000 years earlier than previously reported examples. What most surprised Wadley, however, was the occupants' sophisticated knowledge of the local vegetation. Analysis showed that the chosen leaves came from *Cryptocarya woodii,* a tree containing traces of natural insecticides and larvicides effective against the mosquitoes that carry deadly disease today. "And that's very handy to have in your bedding, particularly if you live near a river," Wadley observes.

The creative minds at Sibudu did not stop there, however. They most likely devised snares to capture small antelopes, whose remains litter the site, and crafted bows and arrows to bring down more dangerous prey, judging from the sizes, shapes and wear patterns of several stone points from the cave. Moreover, Sibudu's hunters concocted various valuable new chemical compounds. By shooting a high-energy beam of charged particles at dark residues on stone points from the cave, Wadley's team detected multi-ingredient glues that once fastened the points to wood hafts. She and her colleagues then set about experimentally replicating these adhesives, mixing ocher particles of different sizes with plant gums and heating the mixtures over wood fires. Publishing the results in *Science,* the team concluded that Sibudu's occupants were very likely "competent chemists, alchemists and pyrotechnologists" by 70,000 years ago.

Elsewhere in southern Africa, researchers have recently turned up traces of many other early inventions. The hunter-gatherers who inhabited Blombos Cave between 100,000 and 72,000 years ago, for example, engraved patterns on chunks of ocher; fashioned bone awls, perhaps for tailoring hide clothing; adorned themselves with strands of shimmering shell beads; and created an artists' studio where they ground red ocher and stored it in the earliest known containers, made from abalone shells. Farther west, at the site of Pinnacle Point, people engineered the stone they worked with 164,000 years ago, heating a low-grade, local rock known as silcrete over a controlled fire to transform it into a lustrous, easily knappable material. "We are seeing behaviors that we didn't even dream about 10 years ago," Henshilwood remarks.

Moreover, technological ingenuity was not the sole preserve of modern humans: other hominins possessed a creative streak, too. In northern Italy a research

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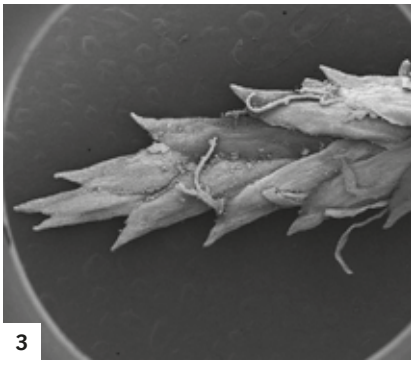

3

ANCIENT WISDOM: Painstaking excavation of Sibudu Cave in South Africa (*1*) has yielded evidence that its inhabitants made bedding (*2*) from insect-repellent plants (*3*) some 77,000 years ago—50,000 years before the previously known examples of this technology appeared.

team headed by University of Florence archaeologist Paul Peter Anthony Mazza discovered that our near kin, the Neandertals, who first emerged in Europe some 300,000 years ago, concocted a birch bark–tar glue to fasten stone flakes to wood handles, fabricating hafted tools some 200,000 years ago. Likewise, a study published in 2012 in *Science* concluded that stone points from the site of Kathu Pan 1 in South Africa once formed the lethal tips of 500,000-year-old spears, presumably belonging to *Homo heidelbergensis,* the last common ancestor of Neandertals and *H. sapiens*. And at Wonderwerk Cave in South Africa, an ancient layer containing plant ash and bits of burned bone suggests that an even earlier hominin, *Homo erectus,* learned to kindle fires for warmth and protection from predators as early as one million years ago.

Even our very distant ancestors were capable on occasion of coining new ideas. At two sites near the Kada Gona River in Ethiopia, a team led by paleoanthropologist Sileshi Semaw of Indiana University Bloomington found stone tools—2.6-million-year-old choppers knapped by *Australopithecus garhi* or one of its contemporaries, likely for stripping meat from animal carcasses. Such tools look crude to us, a far cry from the smartphones, laptops and tablets of today. "But when the world consisted solely of naturally formed objects, the capacity to imagine something and turn it into a reality may well have seemed almost magical," wrote cognitive scientist Liane Gabora of the University of British Columbia and psychologist Scott Barry Kaufman, now at the University of Pennsylvania, in a chapter in *The Cambridge Handbook of Creativity* (2010).

Cognition and Creation

Yet impressive as these early flashes of creativity are, the great disparity in the depth and breadth of innovation between modern humans and our distant forebears demands an explanation. What changes in the brain set our kind apart from our predecessors? By poring over three-dimensional scans of ancient hominin braincases and by examining the brains of our nearest living evolutionary kin—chimpanzees and bonobos, whose ancestors branched off from our lineage some six million years ago—researchers are beginning to unlock this puzzle.

THE AUTHOR

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Their data show just how extensively human gray matter evolved over time.

Generally speaking, natural selection favored large brains in humans. Whereas our australopithecine kin possessed an estimated mean cranial capacity of 450 cubic centimeters, roughly that of some chimpanzees, *H. erectus* more than doubled that capacity by 1.6 million years ago, with a mean of 930 cubic centimeters. And by 100,000 years ago *H. sapiens* had a mean capacity of 1,330 cubic centimeters. Inside this spacious braincase, an estimated 100 billion neurons processed information and transmitted it along nearly 165,000 kilometers of myelinated nerve fibers and across some 0.15 quadrillion synapses. "And if you look at what this correlates with in the archaeological record," says Dean Falk, a paleoneurologist at Florida State University, "there does seem to be an association between brain size and technology or intellectual productivity."

"IT'S NOT HOW SMART YOU ARE. IT'S **HOW WELL CONNECTED YOU ARE.**"

—MARK THOMAS, UNIVERSITY COLLEGE LONDON

But size was not the only major change over time. At the University of California, San Diego, biological anthropologist Katerina Semendeferi studies a part of the brain known as the prefrontal cortex, which appears to orchestrate thought and action to accomplish goals. Examining this region in modern humans and in both chimpanzees and bonobos, Semendeferi and her colleagues discovered that several key subareas underwent a major reorganization during hominin evolution. Brodmann area 10, for example—which is implicated in bringing plans to fruition and organizing sensory input—nearly doubled in volume after chimpanzees and bonobos branched off from our human lineage. Moreover, the horizontal spaces between neurons in this subarea widened by nearly 50 percent, creating more room for axons and dendrites. "This means that you can have more complicated connections and ones that go farther away, so you can get more complex and more synthetic communication between neurons," Falk comments.

Pinpointing just how a bigger, reorganized brain spurred creativity is a tricky business. But Gabora thinks that psychological studies of creative people today supply a key clue. Such individuals are excellent woolgatherers, she explains. When tackling a problem, they first let their minds wander, allowing one memory or thought to spontaneously conjure up another. This free association encourages analogies and gives rise to thoughts that break out of the box. Then, as these individuals settle on a vague idea for a solution, they switch to a more analytic mode of thought. "They zero in on only the most relevant properties," Gabora says, and they start refining an idea to make it workable.

In all likelihood, Gabora notes, a bigger brain led to a greater ability to free-associate. More stimuli could be encoded in a brain made up of many billions of neurons. In addition, more neurons could participate in the encoding of a particular episode, leading to a finer-grained memory and more potential routes for associating one stimulus with another. Imagine, Gabora says, that a hominin brushes against a spiny shrub and sharp thorns tear its flesh. An australopithecine might encode this episode very simply—as a minor pain and as an identifiable feature of the shrub. But *H. erectus*, with its larger assembly of neurons, could conceivably encode many aspects of the episode. Then, when this hominin begins hunting, its need to kill prey might activate all memory locations encoding torn flesh, bringing to mind the encounter with the sharp, pointed thorns. That memory, in turn, could inspire a fresh idea for a weapon: a spear with a sharp pointed tip.

But large-brained hominins could not afford to linger too long in an associative state in which one thing immediately reminded them of a flood of other things, both important and inconsequential. Their survival depended mostly on analytic thought—the default mode. So our ancestors had to develop a way of switching smoothly from one mode to another by subtly altering concentrations of dopamine and other neurotransmitters.

Gabora now hypothesizes that *H. sapiens* needed tens of thousands of years to fine-tune this mechanism before they could reap the full creative benefit of their large brains, and she and her students are testing these ideas on an artificial neural network. Through a computer model, they simulate the brain's ability to switch between the analytic and associative mode to see how it could help someone break out of a cognitive rut and see things in a new way. "Just having more neurons isn't enough," Gabora asserts. "You have to be able to make use of all that extra gray matter." Once that final piece of the biological puzzle fell into place—perhaps a little more than 100,000 years ago—the ancestral mind was a virtual tinder box, awaiting the right social circumstances to burst into flame.

Building on Brilliance

In the autumn of 1987 two researchers, both then at the University of Zurich—Christophe and Hedwige Boesch—observed a behavior they had never seen before in a group of chimpanzees foraging for food in Tai National Park in Ivory Coast. Near a ground nest belonging to a species of driver ants, a female stopped and picked up a twig. She dipped one end into the loose soil covering the nest's entrance and waited for the colony's soldier ants to attack. When the dark swarm had advanced nearly 10 centimeters up the twig, the female chimpanzee plucked it from the nest and deftly rolled it toward her mouth, snacking on the ants. She then repeated the process until she had eaten her fill.

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Chimpanzees are highly adept at using a wide range of tools—cracking open nuts with stones, sponging up water from tree hollows with leaves and unearthing nutritious plant roots with digging sticks. But they seem unable to build on this knowledge or to craft ever more advanced technology. "Chimps can show other chimps how to hunt termites," Henshilwood says, "but they don't improve on it, they don't say, 'Let's do it with a different kind of probe'—they just do the same thing over and over." Modern humans, in contrast, suffer from no such limitations. Indeed, we daily take the ideas of others and put our own twist on them, adding one modification after another, until we end up with something new and very complex. No one individual, for example, came up with all the intricate technology embedded in a laptop computer: such technological achievements arise from the creative insights of generations of inventors.

Anthropologists call this knack of ours cultural ratcheting. It requires, first and foremost, the ability to pass on knowledge from one individual to another or from one generation to the next, until someone comes along with an idea for an improvement.

In a 2012 study published in *Science,* Lewis Dean, a behavioral primatologist at the University of St. Andrews in Scotland, and four colleagues revealed why human beings can do this and chimpanzees and capuchin monkeys cannot. Dean and his team designed an experimental puzzle box, with three sequential and incrementally difficult levels: then they presented it to groups of chimps in Texas, capuchin monkeys in France and nursery schoolchildren in England. Only one of the 55 nonhuman primates—a chimp—reached the highest level after more than 30 hours of trying. The children, however, fared far better. Unlike the groups of monkeys, the children worked collaboratively—talking among themselves, offering encouragement and showing one another the right way to do things. After two and a half hours, 15 of the 35 children had reached level three.

Equipped with these social skills and cognitive abilities, our ancestors could readily transmit knowledge to others—a key prerequisite for cultural ratcheting. Yet something else was needed to propel the ratcheting process and push *H. sapiens* to new creative heights in Africa some 90,000 to 60,000 years ago and in Europe 40,000 years ago. Mark Thomas, an evolutionary geneticist at University College London, thinks this push came from demography. His premise is simple. The larger a hunter-gatherer group is, the greater the chances are that one member will dream up an idea that could advance a technology. Moreover, individuals in a large group who frequently rubbed shoulders with neighbors had a better chance of learning a new innovation than those in small, isolated groups. "It's not how smart you are," Thomas says. "It's how well connected you are."

To test these ideas, Thomas and two colleagues developed a computer model to simulate the effects of demography on the ratcheting process. With genetic data from modern Europeans, the team estimated the size of modern human populations in Europe at the beginning of the Upper Paleolithic, when evidence of human creativity started to spike, and calculated the population density. Then the researchers examined African populations over time, simulating their growth and patterns of migratory activity. Their model showed that African populations reached the same density as the early Upper Paleolithic Europeans around 101,000 years ago, just before innovation began to take off in sub-Saharan regions, according to the archaeological record. It also showed that large social networks actively spur human creativity.

Archaeological evidence published in 2012 in *Nature* sheds light on the tech renaissance that followed the rise of population density in southern Africa. Some 71,000 years ago at Pinnacle Point, *H. sapiens* devised and passed down to others a complex technological recipe to make lightweight stone blades for projectile weapons—cooking silcrete to a specific temperature to improve its flaking qualities, knapping the finished material into blades little more than a couple of centimeters long, and mounting them on wood or bone shafts with homemade glue. "Like viruses," note archaeologists Fiona Coward of Bournemouth University and Matt Grove of the University of Liverpool in England in a paper published in 2011 in *PaleoAnthropology*,"cultural innovations need very particular social conditions to spread—most notably… large connected populations who can 'infect' one another."

Which brings us to the jostling, teeming, intimately linked world we live in today. Never before have humans crowded together in such massive cities, accessing vast realms of knowledge with a click of the keyboard and sharing new concepts, new blueprints and designs across the sprawling social networks of the World Wide Web. And never before has the pace of innovation accelerated so dramatically, filling our lives with new fashions, new electronics, new cars, new music, new architecture.

Half a millennium after Leonardo da Vinci conceived of his most celebrated work, we marvel at his inventive genius—a genius built on the countless ideas and inventions of a lineage of artists stretching back into the Paleolithic past. And even now a new crop of artists gaze at the *Mona Lisa* with an eye to turning it into something fresh and dazzlingly creative. The human chain of invention remains unbroken, and in our superbly connected world, our singular talent to create races on ahead of us. **M**

MORE TO EXPLORE

- **Middle Stone Age Bedding Construction and Settlement Patterns at Sibudu, South Africa.** Lyn Wadley et al. in *Science,* Vol. 334, pages 1388–1391; December 9, 2011.
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PREDICTING ARTISTIC BRILLIANCE

A "RAGE TO MASTER," AS OBSERVED IN SOME PRECOCIOUS YOUNG ARTISTS, MAY HELP DEFINE EXTREME VISUAL CREATIVITY

By Jennifer E. Drake and Ellen Winner

By the time he was seven years old, Arkin Rai, a child living in Singapore, drew dinosaurs with exquisite realism. At age three his dinosaurs were simple and schematic. A year and some months later, however, he created a complex drawing in which dinosaurs were layered one on top of the other, an image that bears an uncanny resemblance to a drawing of horses and a bull by the adult Pablo Picasso.

In Arkin's fanciful scene, the long, graceful neck of an *Apatosaurus*-like beast obscures the view of other dinosaurs. One of them is a *Tyrannosaurus rex*, drawn in profile with one leg mostly hidden behind another—an effect called occlusion, which most children discover at age eight or nine.

FAST FACTS

MOTIVATED TO MASTER

❶ Artistically gifted children may see the world differently than other youngsters do. They are able to discover advanced compositional techniques many years before their peers.

❷ These precocious children tend to be self-motivated and deeply interested in honing their skills.

❸ These early signs and others are helping researchers to predict which children are likely to pursue art as adults.

LUCY SCHAEFFER

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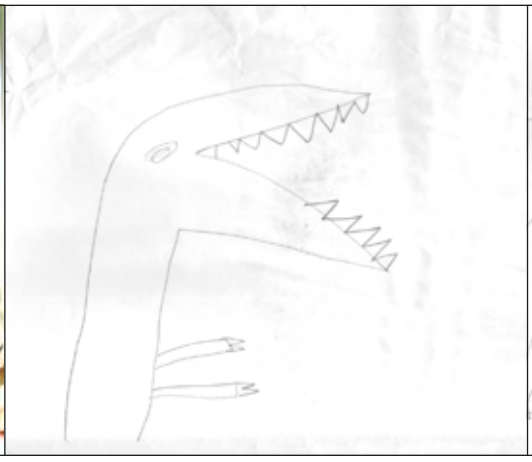

Age 3

Age 4 years, 7 months

In one and a half years, Arkin Rai went from creating abstract, schematic drawings (*age 3*) to learning several advanced techniques, such as the occlusion of one leg by another (*age 4 years, 7 months*). His later sketches also show layering, foreshortening and linear perspective.

In the ensuing months his drawings became shockingly realistic. He started using fluid contour lines to give figures shape. At age six he was depicting dinosaurs fighting and running, using various advanced methods to convey the distance between objects.

Most adults cannot draw anywhere near as realistically as Arkin can, and we are in awe of such technical virtuosity in a young child. Although we cannot know if Arkin will develop into a professional artist, his drawings and those of children like him are helping us study the emergence of artistic ability. By examining the artworks of gifted children and the early compositions of adult artists, we and other researchers have begun to predict who will display great visual creativity later in life. Our studies of young artists may also offer insight into the development of mastery more generally.

PRECOCIOUS ARTISTS BEGIN TO DRAW REPRESENTATIONALLY BY AGE TWO, AT LEAST ONE YEAR AHEAD OF MOST CHILDREN, WHO DRAW ABSTRACTIONS.

Exceptional realism, such as that displayed by Arkin, is one important sign, but it is not the whole story. Not all adult artists drew as convincingly as Arkin when they were his age, and some young children are now being discovered who show a skill for producing nonrepresentational art rather than realistic works. We have identified five other characteristics that we believe foretell artistic creativity. A budding artist's drawings are often well composed and display either a decorative, colorful aspect or an expressive power. The child also has a hunger to look at art, possesses an enormous drive to create and wants to be original. Last, we contend that outstanding artists, and perhaps geniuses in all domains, not only possess innate talent but also are intrinsically motivated in a way that others may not be—something we call the rage to master.

Birth of a Skill

Scientists and educators have long sought to demystify the emergence of expertise, artistic and otherwise. Many researchers have argued that exceptional achievement can be boiled down simply to hard work—about 10,000 hours of it. Studies of eminent scientists in the 1950s supported this view by underscoring the individuals' capacity for endurance, concentration and commitment to effortful practice. Benjamin Bloom, a prominent education psychologist who studied mastery, wrote in 1985 that none of his subjects achieved expertise without a supportive environment and a long and intensive period of training. This education came first from encouraging instructors and later from demanding master teachers. A few years later psychologist K. Anders Ericsson of Florida State University conducted studies of experts in piano, violin, chess, bridge or athletics. The investigations revealed that a person's level of achievement correlated strongly with the amount of practice put in.

These studies, however, have not been able to tease apart hard work and innate ability. The children with the most talent may also be the ones most interested in an activity, who begin to develop their skills at an early age and who work the hardest at it. Committing time and energy to a task likely is easier when advancement comes quickly but not when every step is a painful struggle.

COURTESY OF DINESH RAI (*Rai family*); COURTESY OF ARKIN RAI (*dinosaurs*)

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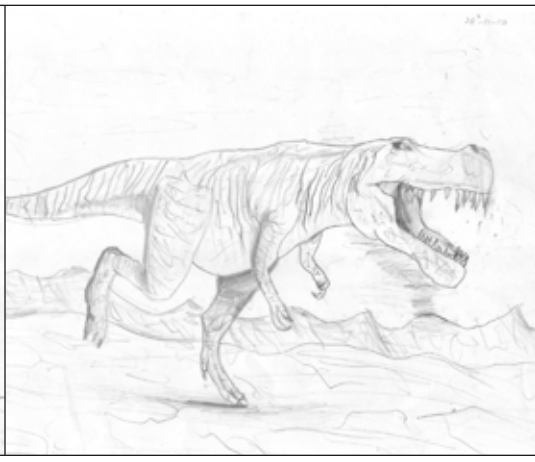
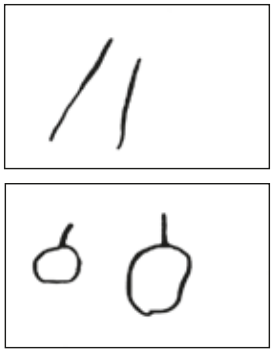
Age 5 years, 1 month

Age 6



Age 6

We have tackled this question by examining the earliest signs of artistic talent. Researchers have long assumed that the first inkling of it in humans, and especially in the young child, is the ability to portray the three-dimensional world realistically on a two-dimensional surface. Art historians have been struck by the realism of the cave paintings done by our Paleolithic forebears, leading many to assume that this style is the most natural form of art. Although most children's drawings are schematic, certain youngsters, including some with autism, can draw in a highly naturalistic fashion from a very early age, mirroring those paintings done by our ancestors. We refer to children who show an early ability to draw in this manner as precocious realists, and we now know a great deal about their developmental trajectory.



A typical two-year-old's drawing of two apples uses two lines. A precocious two-year-old draws a circular line to capture contour.

Precocious realists begin to draw representationally by age two, at least one year ahead of most children. The artworks of typically developing youngsters are abstractions: an apple is captured with a slash, a human body with a circle, a horse's body with a square. Precocious realists produce works that are much more optically convincing.

These children discover on their own how to create the illusion of 3-D using depth cues—foreshortening, occlusion, size diminution, shading to convey form and, the most difficult technique of all, linear perspective—years before most of their peers. In a comparison of typical and precocious artists published in 1995, psychologist Constance Milbrath, now at the University of British Columbia, observed that half of the children in the precocious group used foreshortening, in which lines not parallel to the picture plane are drawn shorter, in their artworks by ages seven and eight. Typically developing children reached comparable levels only by ages 13 and 14.

The ability to draw realistically at an early age marks the childhoods of many recognized artists. Artist and former curator Ayala Gordon observed naturalism in the childhood compositions of 31 Israeli artists. Many famous artists' early drawings have been singled out for advanced realism, too, including Picasso, John Everett Millais, Edwin Henry Landseer, John Singer Sargent, Paul Klee and Henri de Toulouse-Lautrec. Picasso recalled one of his first drawings in this way: "I was perhaps six.... In my father's house there was a statue of Hercules with his club in the corridor, and I drew Hercules. But it wasn't a child's drawing. It was a real drawing, representing Hercules with his club."

Different Way of Seeing

We set out to discover what cognitive differences might give these children their edge. Their skill is not a matter of intelligence. As we reported in 2010, we have observed no relation between realistic drawing ability and IQ. This finding is bolstered by the cases of autistic "savants" with low IQs, such as Nadia, a child discovered at age six who demonstrated phenomenal artistic prowess despite severe learning disabilities, and Stephen Wiltshire, a man with autism who could draw elaborate cityscapes from memory after only a brief exposure to a scene.

What we have found instead is that children who draw realistically at an above-average level dif-

COURTESY OF ELLEN WINNER

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THE DESIRE TO WORK SO HARD AT SOMETHING COMES FROM WITHIN. A CHILD'S INTEREST AND DRIVE CANNOT BE SEPARATED FROM THE TALENT.

fer in their perceptual abilities. They have strong observational skills and seem to be able to just see the shapes of things, including the distortions that occur as objects recede into depth and diminish in size. A typical child might see a road as having parallel sides because she knows that a road's edges are parallel, whereas an artistically gifted child overrides her knowledge about the road and sees its sides converging in the distance.

Early artistic aptitude is also strongly associated with the ability to focus on the parts of an object or scene rather than on the whole. To examine this idea, we used a visual and motor skills test called the Block Design Task. Children were asked to arrange red and white blocks to match a given pattern. We gave this task once in traditional format and once with the pattern segmented to reveal where the block boundaries should be. All participants did well on the segmented version. Children with realistic drawing ability, however, performed much better than other kids on the unsegmented version, presumably because they could mentally divide a complex form into its parts with ease.

They also performed better on a task in which they were asked to detect small shapes hidden within figures, a skill that requires analyzing a form by its elements. We hypothesize that a focus on component parts characterizes the process by which realistic artists draw. They may create a complex drawing not by first sketching the global outline but by building up their drawings part by part. Thus, they may both process and generate a scene with a more local focus than do nonartists.

This local-processing bias is also seen in children with autism. In 1993, for example, psychologists Amitta Shah, now a consultant, and Uta Frith of University College London found that autistic children performed equally well on both versions of the Block Design Task. Although a local-processing bias is commonly thought of as a characteristic of autism, our work has found that this proclivity is predicted not by the presence or absence of autism but only by the ability to draw realistically.

Nonrepresentational Painters

We suspect, however, that producing works in a naturalistic style is not the only way to demonstrate artistic brilliance. Although most Western children identified as gifted in drawing have come to our attention by virtue of their precocious realism, some talented children have mastered a nonrealistic style instead. Psychologist Claire Golomb of the University of Massachusetts Boston has described these children, whom she called "colorists," as showing an awareness of form and quality and a concern with decorative and expressive aspects of color, texture and design. These artists are more difficult for an untrained eye to spot because their drawings may look similar to the charming, nonrealistic paintings of typical preschoolers.

We have discovered a child, whom we classify as artistically gifted, whose paintings are entirely nonrepresentational. His process did not resemble that of his peers, nor did his works. Several days shy of his second birthday, Arrian began to create colorful abstract drawings on large, 18- × 24-inch pages using Crayola markers, concentrating intensely. He usually worked on each drawing for a day and a half to two days.

At age 12, avid naturalist Joel Gilb displayed artistic talent but might have been using drawing as a tool to understand nature. Might he become a scientist instead?

COURTESY OF JOEL GILB

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He filled the entire space densely and meticulously. As his mother described it:

> One session for Arrian is typically a cycle through whatever set of markers he is using at the time. So, if he has a set of 24 he will systematically go through each marker one by one.... He often begins with some circles all over the page and long flowing lines.... Once he has his basic drawing he colors it in systematically—almost in quadrants.

A few months later Arrian's mother noted:

> Ari is obsessed with making circles—he tries for hours to make the smallest, tightest, thinnest circles he can do. He tries all kinds of ways of holding the marker ... experiments with putting his face really close to the page. He likes to dangle the marker to get a thin feather line, but then he tries with his fist to get a tighter circle—to hold it properly to gain control, and ultimately [he] seems to want to achieve some combination of all three to get the look he wants. He's been doing this all day for a week—sometimes with just one or two colors.

When Arrian turned three, he discovered viewfinders. For two weeks he carried around a comb through which he inspected the world. He also started drawing people at this time, right on track with typical development. Notably, he was not ahead of the curve in representational skill. He was, however, advanced in intensity: after drawing one face—a circle with eyes—he went on to draw about 400 more smiling visages, all in one sitting. The systematicity, intensity, focus and meticulous care with which Arrian drew set him apart from the typical two-year-old scribbler. None of the precocious realists we have studied show anything like Arrian's behavior—they progressed rapidly to representational drawings and showed no interest in nonrepresentational art.

A Rage to Master

Arrian drew constantly and compulsively. So do the precocious realists. This kind of rage to master cannot be taught, cajoled or forced. The children we study often have to be dragged away from their preferred activities to eat, sleep, go to school or be sociable. The desire to work so hard comes from within, and it almost always occurs when a child can achieve at high levels with relative ease. The interest and drive cannot be separated from the talent.

Most gifted child artists do not become artists as adults, of course. Many individuals have displayed skill in their early work as great as that of Picasso, yet only one person became Picasso. The age at which extreme realism emerges is also not predictive: Klee's drawings at age six were less realistic than those of some of the children whose work is reprinted in this article, yet he is among the greats.

Gifted individuals may choose not to pursue art for many reasons, but one explanation might have to do with the child's underlying motivation. Some precocious realists seem more interested in understanding nature—drawing is their tool. Rocco Roth and Joel Gilb exemplify this mindset. Both boys pored over nature encyclopedias and field guides. Rocco, at age six, was passionate about insects,

At age two years and three months, Arrian (*shown above*) worked for five days to create this 18- x 24-inch painting. He used Crayola markers to fill the page with small marks, sometimes drawing with the right hand and sometimes with the left.

COURTESY OF ARRIAN AND REBECCA SMITH (*abstract drawing*); COURTESY OF BRANDON SMITH (*Arrian*)

THE AUTHORS

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TALENTED TODDLERS?

Parents sometimes believe that their two-year-old is a prodigy because they notice the similarity of their child's painting to that of an abstract expressionist master. Gallery owners, too, have been fooled by such paintings. In 2011, for example, four-year-old Aelita Andre had an exhibit in New York City and was touted as a genius on a par with Jackson Pollock and Wassily Kandinsky. These works, however, are age-typical, and we cannot yet call their maker artistically gifted—even if we find the paintings pleasing and superficially similar to works by abstract expressionists. (The 2007 film *My Kid Could Paint That,* directed by Amir Bar-Lev, asks whether parents and gallery owners are fooling the public into thinking these works are signs of genius.)

Other children, however, truly are precocious artists. Parents can nurture such giftedness when it exists. In the early years parents can encourage art-making behavior, provide high-quality art supplies, and take the child to museums and expose him or her to the range of styles in which artists have worked. Given the lack of attention and time devoted to art education in most schools, the opportunity to study art formally outside of school very likely is critical if the child is to go on to become an artist. In

2011 then curator Ayala Gordon reported that almost all the 31 Israeli artists whose childhoods she studied had begun taking art lessons outside of school with artist-teachers by age 10. It was in these classes that they began to identify themselves as artists and to discover others like themselves. *—J.E.D. and E.W.*

seeds, leaves and vegetables. He collected specimens and then drew and labeled each one. Joel had memorized the *Kaufman Field Guide to Birds of North America* by the time he was 12 years old and made meticulous copies of these drawings. Such children may eventually become scientists rather than artists.

Beyond a realistic drawing skill, we have identified five other commonalities that are likely to be predictive of becoming an artist. The child's drawings have an interesting, arresting composition and decorative, aesthetic features or expressive power. The child shows a hunger to look at art, whether in museums or books, and hence manifests a deep interest in art. The young artist also has enormous drive—a rage to master. Finally, and perhaps most important, the child has a desire not just to make excellent art but to be original and innovative.

We can even speculate that realistic drawing skill might not be necessary. Because so few nonrealistic child prodigies have been identified, we do not yet know the answer to this question. Children who paint abstractly may be more unconventional and playful. They may more readily think out of the box and are thus perhaps more likely than the realists to think like true artists.

As art historian Ernst Gombrich wrote in 1960 in *Art and Illusion,* a classic text on the history of art from a psychological perspective, realism is only one thin slice of the art that humans have produced over the centuries. There may be more than one route to a career in art—one that begins with a striving toward realism and another that emerges from a nonrepresentational exploration of form and color. As studies of children gifted not only in art but also in math, science, languages, chess and athletics have shown, what really predicts high achievement is the lucky combination of an ease of learning, an obsessive focus and a deep motivation to pursue an activity. M

GETTY IMAGES

MORE TO EXPLORE

- **Normal and Anomalous Representational Drawing Ability in Children.** Lorna Selfe. Academic Press, 1983.
- **Eytan: The Early Development of a Gifted Child Artist.** Claire Golomb in *Creativity Research Journal,* Vol. 5, No. 3, pages 265–279; 1992.
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- **Children Gifted in Drawing: The Incidence of Precocious Realism.** Jennifer E. Drake and Ellen Winner in *Gifted Education International,* Vol. 29, No. 2, pages 125–129; May 2012.
- Watch Arrian, a precocious nonrepresentational artist, draw in this video: **www.youtube.com/watch?v=hyJB0shXoD0**

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SO YOU WANT TO BE A GENIUS

WHEN IT COMES TO CULTIVATING GENIUS, TALENT MATTERS, BUT MOTIVATION MAY MATTER MORE

By Daisy Yuhas

Practice makes perfect, but finding the personal wherewithal to start can be daunting. Proved techniques can help build motivation.

KRISTEN GERACI *Getty Images*

Got motivation? Without it, the long, difficult hours of practice that elevate some people above the rest are excruciating. But where does such stamina come from, and can we have some, too? Psychologists have identified three critical elements that support motivation, all of which you can tweak to your benefit.

Autonomy

Whether you pursue an activity for its own sake or because external forces compel you, psychologists Edward L. Deci and Richard M. Ryan of the University of Rochester argue that you gain motivation when you feel in charge. In evaluations of students, athletes and employees, the researchers have found that the perception of autonomy predicts the energy with which individuals pursue a goal.

In 2006 Deci and Ryan, with psychologist Arlen C. Moller, designed several experiments to evaluate the effects of feeling controlled versus self-directed. They found that subjects given the opportunity to select a course of action based on their own opinions (for example, giving a speech for or against teaching psychology in high school) persisted longer in a subsequent puzzle-solving activity than participants who were either given no choice or pressured to select one side over another. Deci and Ryan posit that acting under duress is taxing, whereas pursuing a task you endorse is energizing.

Value

Motivation also blossoms when you stay true to your beliefs and values. Assigning value to an activity can restore one's sense of autonomy, a finding of great interest to educators. In a 2010 review article, educational psychologists Allan Wigfield of the University of Maryland and Jenna Cambria, now at the University of Arkansas, noted that several studies have found a positive correlation between attaching value to a subject in school and a student's willingness to investigate a question independently.

The good news is that value can be modified. In 2009 University of Virginia psychologist Christopher S. Hulleman described a semester-long intervention in which one group of high school students wrote about how science related to their lives and another group simply summarized what they had learned in science class. The most striking results came from students with low expectations of their performance. Those who described the importance of science in their lives improved their grades more and reported greater interest than similar students in the summary-writing group. In short, reflecting on why an activity is meaningful could make you more invested in it.

Competence

As you devote more time to an activity, you notice your skills improve, and you gain a sense of competence. In 2006 psychologists at the Democritus University of Thrace and the University of Thessaly in Greece surveyed 882 students on their attitudes and engagement with athletics during a two-year period. They found a strong link between a student's sense of prowess and his or her desire to pursue sports. The connection worked in both directions—practice made students more likely to consider themselves competent, and a sense of competence strongly predicted that they would engage in athletic activity. Similar studies in music and academics bolster these findings.

Carol S. Dweck, a psychologist at Stanford University, has shown that competence comes from recognizing the basis of accomplishment. In numerous studies, she has found that those who credit innate talents rather than hard work give up more easily when facing a novel challenge because they assume it exceeds their ability. Believing that effort fosters excellence can inspire you to keep learning.

The next time you struggle to lace up your sneakers or park yourself at the piano bench, ask yourself what is missing. Often the answer lies in one of these three areas—feeling forced, finding an activity pointless or doubting your capabilities. Tackling such sources of resistance can strengthen your resolve. The choice, of course, is yours. M

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THE SCIENCE OF GENIUS

OUTSTANDING CREATIVITY IN ALL DOMAINS MAY STEM FROM SHARED ATTRIBUTES AND A COMMON PROCESS OF DISCOVERY

By Dean Keith Simonton
Illustration by Noma Bar

Identifying genius is a dicey venture. Consider, for example, this ranking of "The Top 10 Geniuses" I once stumbled across on Listverse.com. From first to last place, here are the honorees: Johann Wolfgang von Goethe, Leonardo da Vinci, Emanuel Swedenborg, Gottfried Wilhelm Leibniz, John Stuart Mill, Blaise Pascal, Ludwig Wittgenstein, Bobby Fischer, Galileo Galilei and Madame de Staël.

What about Albert Einstein instead of Swedenborg? Some of the living might also deserve this appellation—Stephen Hawking comes to mind. Another female genius or two might make the cut, perhaps Marie Curie or Toni Morrison. And if a chess champion, Fischer, is deemed worthy, other geniuses outside the arts and sciences ought to deserve consideration—Napoleon Bonaparte as a military genius, Nelson Mandela as a political genius or Bill Gates as an entrepreneurial genius, to name a few candidates.

All these questions and their potential answers can make for some lively cocktail party conversations. What they reveal is how little we understand about the origins of intellectual and creative eminence. Explorations of this age-old debate have long sought to tease out the common features of geniuses working in disparate domains. The existence of unifying threads—including genetic factors, unusually broad interests and a link with psychopathy—suggests that the mind of a genius has a discernible shape and disposition.

FAST FACTS
GENIUS, DEFINED

❶ Genius has been viewed two different ways: as achieved eminence and as exceptional intelligence. The former metric offers the more useful definition.

❷ Genetics and life experiences both contribute to genius. Creative contributions can occur only after a domain has been mastered, but genetics can help a person improve faster and accomplish more with a given amount of expertise.

❸ Genius can share certain potentially negative traits with mental illness, but when these traits are combined with specific positive attributes, the result is creativity rather than psychopathology.

❹ A scientific genius has different expertise than an artistic genius, but all creative geniuses may depend on the same general process: blind variation and selective retention.

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Psychologists often assess geniuses by their achievements, such as painting the Sistine Chapel, rather than by IQ scores.

Ultimately the goal is to explain how an eminent thinker arrives at his or her world-changing moment, or moments, of insight. Although such breakthroughs often seem to appear in a flash, the underlying mechanisms are likely to be much more orderly. According to one theory I helped to develop, a genius hunts widely—almost blindly—for a solution to a problem, exploring dead ends and backtracking repeatedly before arriving at the ideal answer. This line of research is helping us to investigate whether genius can be cultivated, unleashing a wealth of new ideas for the benefit of all.

The Meaning of Genius

The first hurdle in the study of genius is to settle on a working definition. The word itself harks back to ancient Roman mythology, according to which every male was born with a unique genius that served as a kind of guardian angel, and every female had a juno. Much later, after the Renaissance, the word became more exclusive in its application, with only a few people showing genius. Philosopher Immanuel Kant believed, for example, that a genius was someone who produced works that were both original and exemplary. The term did not acquire scientific meaning until the late 19th century, when psychologists came to define genius in two distinct ways.

The first approach was to identify genius with exceptional achievement, as Kant did. These accomplishments elicit admiration and emulation from other experts in that field and often the world at large. Unquestioned examples of such works include Newton's *Principia,* Shakespeare's *Hamlet,* Tolstoy's *War and Peace,* Michelangelo's Sistine Chapel frescoes and Beethoven's Fifth Symphony. Even though this definition can be extended to encompass extraordinary leadership, such as military brilliance, and prodigious performance, including some chess grandmasters, most scientific research concentrates on outstanding creativity within the sciences or the arts, which will also be the focus here.

The second definition of genius coincided with the emergence of intelligence tests in the first half of the 20th century. A genius was someone who scored sufficiently high on a standard IQ test—usually landing in the top 1 percent, with a score above 140, as proposed by psychologist Lewis Terman, the formulator of one of the original intelligence tests. These two definitions have little in common. Many persons with superlative IQs do not produce original and exemplary accomplishments. One example is Marilyn vos Savant, who was once certified by the *Guinness Book of World Records* as having the highest recorded IQ of any living person. Her weekly Ask Marilyn column for a Sunday newspaper supplement did not inspire a new genre of science, art or even journalism. And many exception-

FRANK HEUER *Redux Pictures*

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al achievers do not attain genius-level IQs. William Shockley, for example, received a Nobel Prize in Physics for coinventing the transistor yet had an IQ score well below 140. Exceptional achievement, then, seems the more useful measure.

Too often in popular writing, genius is conceived as a discrete category—this person is a genius, but that person is not.

GENIUSES ARE LIKELY TO EXHIBIT UNUSUALLY WIDE INTERESTS AND HOBBIES, OFTEN CONTRIBUTING TO MORE THAN ONE DOMAIN OF EXPERTISE.

Yet just as people can vary in IQ, they can also differ in the magnitude of their creative achievements, with either a single notable contribution or a lifetime of prolific work. One such "one-hit wonder" is Gregor Mendel, who attained lasting fame for a single paper that reported his classic experiments in genetics. Had Mendel never taken an interest in breeding peas, his name would be unknown today. Charles Darwin's fame, in contrast, rests on far more than *On the Origin of Species*. Nobel laureate Max Born once said that Einstein "would be one of the greatest theoretical physicists of all time even if he had not written a single line on relativity." Hence, Darwin and Einstein exhibited greater genius than did Mendel. Accordingly, much research is devoted to assessing relative degrees of genius—most often gauged by creative productivity.

Origins of Genius

Finding the sources of consummate creativity has occupied the minds of philosophers and scientists for centuries. In 1693 English poet John Dryden wrote, "Genius must be born, and never can be taught." Two and a half centuries later French author Simone de Beauvoir countered, "One is not born a genius, one becomes a genius." The first scientific investigation devoted exclusively to genius concerned this precise issue. In 1869 Francis Galton published *Hereditary Genius,* in which he argued that genius is innate, based on his observations that geniuses tend to emerge from lineages that included other brilliant individuals. In response to criticisms, Galton later introduced the well-known nature-nurture issue. He conducted a survey of famous English scientists to discover some of the environmental variables involved in nurturing brilliance, and he examined factors such as birth order and education.

By the second half of the 20th century psychologists had moved to an extreme nurture position, in which creative genius rested solely on the acquisition of domain expertise. This idea was frequently expressed as the "10-year rule." Nobody can expect to reach the heights of creativity without mastering the necessary knowledge and skill because only experts can create—or so the thinking went. Indeed, Einstein learned lots of physics before he commenced his creative career.

This explanation cannot account for all the details, however. First, geniuses often spend less time acquiring domain expertise than their less creative colleagues. Studies have linked accelerated acquisition with long, prolific and high-impact careers. The 10-year rule is an average with tremendous variation around the mean. Further, major breakthroughs often occur in areas where the genius must create the necessary expertise from scratch. Telescopic astronomy did not exist until Galileo pointed his new instrument toward the night sky to discover what had never been seen before nor even expected. The moon had mountains, Jupiter had moons and the sun had spots!

Second, geniuses are more likely to exhibit unusually wide interests and hobbies and to display exceptional versatility, often contributing to more than one domain of expertise. This tendency not only was true in the era of Renaissance men but also is evident today. According to a 2008 study, Nobel laureates in science are more involved in the arts than less eminent scientists. Given that geniuses might not sleep any less than the rest of us, these extraneous activities would seem to distract from a dogged focus on a narrow field of interest. Einstein slept even more hours than the norm, but he still took time off to play Bach, Mozart and Schubert on his violin. At times these avocational activities inspire major insights. Galileo was probably able to identify the lunar mountains because of his training in the visual arts, particularly in the use of chiaroscuro to depict light and shadow.

To build the two-lens telescope he used to survey the skies, Galileo had to first learn how to grind his own lenses and discover the optimal lens combination.

The expertise acquisition theory also undervalues the genetic components that underlie a large number of cognitive abilities and personality traits that correlate with genius. In a 2008 meta-analysis, I found that at least 20 percent of the variation in creativity could be attributed to nature. For exam-

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MEASURING GENIUS

In 1926 Catharine Cox estimated the IQs of 301 eminent individuals. Using biographical data on early intellectual development, she and her collaborators calculated IQ using the formula IQ = 100 × MA/CA, where MA = mental age and CA = chronological age. Some representative results are shown here. (The actual scores are taken from a secondary analysis of her data that I published with Anna V. Song of the University of California, Merced.) These rankings illustrate the value of using achieved eminence, rather than intelligence test scores, as a measure of genius. Philosopher George Berkeley, for example, did not leave a greater mark on the world than Newton or Leonardo. Further, eight of these creative geniuses have IQs below the "genius threshold" of 140. —*D.K.S.*

IQs	Scientists	Philosophers	Writers	Artists	Composers
190s		Gottfried Wilhelm Leibniz	Johann Wolfgang von Goethe		
180s	Blaise Pascal	John Stuart Mill	Voltaire		
170s	Pierre-Simon Laplace	George Berkeley	Samuel Taylor Coleridge		
160s	Isaac Newton	René Descartes	Charles Dickens	Michelangelo	
150s	Johannes Kepler	Baruch Spinoza	Michel de Montaigne	Leonardo da Vinci	Wolfgang Amadeus Mozart
140s	Charles Darwin	Emanuel Swedenborg	Molière	Peter Paul Rubens	Ludwig van Beethoven
130s	Nicolaus Copernicus	Jean-Jacques Rousseau	Robert Burns	Rembrandt van Rijn	Gioachino Rossini
120s			Miguel de Cervantes	Bartolomé Esteban Murillo	Cristoph Willibald Gluck

ple, creative achievement is strongly associated with the personality trait of openness to experience, a highly heritable characteristic. The broad interests in art and music of many geniuses are clear manifestations of this trait. Many other predictors of achievement also have high heritabilities, such as cognitive and behavioral flexibility, along with a tolerance of ambiguity and change.

Nurture may still account for the lion's share of genius, and mastering a domain remains central. At the same time, genetics contributes heavily to the rate at which someone acquires the necessary skills and knowledge. Those with more innate talent can improve faster, launch their careers earlier and be more productive. In addition, genetics may help explain the different trajectories of equally well-trained individuals. Einstein did not know as much physics as many of his contemporary theoretical physicists, but what he did know went a long way. He could honestly say, "Imagination is more important than knowledge."

These influences are just a few of the ways genetics shapes the potential for genius. Let it suffice to note that I have probably understated the impact of genes on genius.

Madness and Magnificence

Researchers have long been tantalized by the question of whether the biological endowment of a genius also confers great setbacks. Greek philosopher Aristotle is reputed to have said, "Those who have become eminent in philosophy, politics, poetry and the arts have all had tendencies toward melancholia."

This idea received wide currency in

WHEN HIGH IQS HANG OUT

"Genius" societies offer a social network for the top tier of test takers **By Lena Groeger**

Kevin Langdon was writing several books and designing an inside-out clock. Karyn Huntting Peters was organizing a global problem-solving network. Alfred Simpson juggled multiple Web-programming projects in his free time. These three people might not have had much in common—except for their unusually high IQs.

All three belong to exclusive high-IQ societies. Mensa International, whose members' test scores must land above the 98th percentile (or one in 50), may be the most popular, but it is just one option for the discerning test taker. The Triple Nine Society demands an IQ in the 99.9th percentile, whereas the Mega Society cuts off at the 99.9999th percentile (one in one million). The memberless Grail Society claims to accept one in 100 billion people—no one has applied so far.

Although members of IQ societies do not fit a single profile, they often join in search of a sense of belonging. "I've heard a lot of people refer to themselves as aliens until they found a group like this," says Peters, who serves as

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the 19th and 20th centuries at the hands of psychiatrists and psychoanalysts. Among the great writers, Virginia Woolf, Anne Sexton and Sylvia Plath all committed suicide. Vincent van Gogh did as well, and earlier he had cut off part of his ear to give to a prostitute. Newton sometimes suffered from extreme paranoia, and Galileo, possibly an alcoholic, was often bedridden with depression. Nevertheless, many psychologists have argued that such cases are the exceptions, not the rule. Some positive psychologists today consider creative genius a human strength or virtue.

My 2005 review of the literature, which summarized studies with varied methodologies, indicates that the association between genius and mental illness has considerable strength. Very creative writers tend to obtain higher scores on the psychopathology-related parts of the Minnesota Multiphasic Personality Inventory, a widely accepted personality test. A study using another instrument, the Eysenck Personality Questionnaire, found that extremely creative artists—and high-impact psychologists, for that matter—tend to receive elevated scores on the test's psychoticism scale, meaning that they are, among other things, egocentric, cold, impulsive, aggressive and tough-minded. Last, highly eminent scientists tend to score higher on sections of the Cattell 16 Personality Factor Questionnaire that signify they are withdrawn, solemn, internally preoccupied, precise and critical. All told, top performers are not a very normal bunch.

Psychiatric studies bolster these results. The rate and intensity of certain psychopathic symptoms, such as depression and alcoholism, are noticeably higher in very creative individuals than in the general population. Research also suggests that these divergent thinkers are more likely to come from family lines that are at higher risk for psychopathology. Even if an extraordinary innovator is "normal," his or her family members may not be.

In line with these findings, in 2009 psychiatrist Szabolcs Kéri, then at Semmelweis University in Hungary, found a genetic basis for both creativity and psychosis in a variant of the *neuregulin 1* gene. In this study, Kéri recruited a group of highly creative individuals and found that the participants who had this specific gene variant, which is linked with an increased risk of developing a mental disorder, also scored higher on measures of creativity.

Out-and-out psychosis, however, can shut down creative genius. This tragic reality was dramatically illustrated in the 2001 film *A Beautiful Mind*, the biopic about the late Nobel laureate John Nash and his struggles with schizophrenia. The costs and burdens of psychological dysfunction are also immediately apparent in the art of the mentally ill, such as the works preserved in the Prinzhorn Collection in Heidelberg, Germany, done by psychiatric patients in the early 20th century. Few if any of these artworks show signs of genius. To quote Dryden again, "wits are sure to madness near allied, and thin partitions do their bounds divide."

Research conducted by psychologist Shelley Carson of Harvard University and her colleagues sought to identify these thin partitions. Creative achievement is positively associated both with cognitive disinhibition—openness to sup-

THE RATE AND INTENSITY OF CERTAIN PSYCHOPATHIC SYMPTOMS ARE NOTICEABLY HIGHER IN VERY CREATIVE PEOPLE THAN IN OTHERS.

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an officer of the Prometheus Society. "But get them all together, and they become extremely talkative—they're up until five in the morning." Langdon, who has founded or co-founded several high-IQ societies and now edits the journal of the Mega Society, also reports having joined to find people more like himself.

Others do it for the challenge. "I joined Prometheus just to see if I could," Simpson says. He now deals with the society's membership requests. He receives about two or three a week, although only three or four new members are accepted every year. The admissions process for these societies usually hinges on a score on an approved test, some of which have names such as Mega or Titan. Typical questions include analogies, the manipulation of complex three-dimensional shapes, or word problems that must be translated into equations.

Critics question whether IQ tests measure intelligence accurately, but "genius" societies rarely claim to represent true genius: the merging of intellect, creativity and outstanding achievement. Peters notes that her high-IQ colleagues are acutely aware of their own ignorance. Simpson concurs. "None of us consider ourselves a 'genius,'" he says. "Well, maybe there's this one guy, but he hasn't been in the society for a while now."

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International Society for Philosophical Enquiry	One in a Thousand Society	Vertex Society	Prometheus Society	Mega Society
1/1,000	1/1,000	1/11,000	1/11,000	1/1,000,000

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PABLO PICASSO'S CHAOTIC PROCESS

In dozens of sketches for his painting *Guernica,* Picasso explored numerous styles. A sampling of his drawings of the bull (*shown with Picasso's original numbering*) reveals the breadth of his exploration. Hunting widely for answers, abandoning some ideas and backtracking to earlier concepts are hallmarks of a theory of creativity known as blind variation and selective retention.

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posedly extraneous ideas, images or stimuli—and higher intelligence and greater working memory. These mental capacities can potentially ameliorate the negative effects of cognitive disinhibition and even channel them to more useful ends. This synergy may well constitute the cognitive basis for serendipity. Not everybody would be able to work out the profound implications of such humdrum events as water overflowing a bathtub or an apple falling from a tree. But Archimedes and Newton did. [For more on creativity and eccentricity, see "The Unleashed Mind," by Shelley Carson, on page 28.]

Thinking Outside the Box

Archimedes and Newton both worked in scientific fields, raising the possibility that their brands of creativity may have been similar. A more revealing question might be to investigate how their route to original thought compares with that of a superlative writer or musician. A physicist's way of thinking has little, if anything, in common with that of a painter. For example, learning how to solve a differential equation has as much utility for a painter as learning linear perspective has for a physicist—zero in most cases. Yet the themes uniting geniuses, as discussed earlier, suggest that a common creative principle may exist. Domain ex-

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pertise, such as the knowledge of advanced problem-solving strategies, supports thinking that is routine, even algorithmic—it does not inherently lead to the generation of novel, useful and surprising ideas. Something else must permit a person to go beyond tradition and training to reach the summit of genius.

According to a theory proposed in 1960 by psychologist Donald Campbell, creative thought emerges through a process or procedure he termed blind variation and selective retention (BVSR). In short, a creator must try out ideas that might fail before hitting on a breakthrough. Campbell did not precisely define what counts as a blind variation, nor did he discuss in any detail the psychological underpinnings of this process. As a result, his ideas were left open to criticism.

Using a mixture of historical analyses, laboratory experiments, computer simulations, mathematical models and case studies, I have developed BVSR into a comprehensive theory of creative genius in all domains. The blindness of BVSR merely means that ideas are produced without foresight into their eventual utility. The creator must engage in trial-and-error or generate-and-test procedures to determine the worth of an idea. Two common phenomena characterize BVSR thinking: superfluity and backtracking. Superfluity means that the creator generates a variety of ideas, one or more of which turn out to be useless. Backtracking signifies that the creator must often return to an earlier approach after blindly going off in the wrong direction. Superfluity and backtracking are often found together in the same creative episode. Exploring the wrong track obliges a return to options that had been originally cast aside.

The reflections of Hermann von Helmholtz, a prolific physicist with numerous creative breakthroughs to his name, capture this process of discovery:

> I had to compare myself with an Alpine climber, who, not knowing the way, ascends slowly and with toil, and is often compelled to retrace his steps because his progress is stopped; sometimes by reasoning, and sometimes by accident, he hits upon traces of a fresh path, which again leads him a little further; and finally, when he has reached the goal, he finds to his annoyance a royal road on which he might have ridden up if he had been clever enough to find the right starting point at the outset.

COGNITIVE DISINHIBITION, HIGHER INTELLIGENCE AND GREATER WORKING MEMORY MAY CONSTITUTE THE BASIS FOR SERENDIPITY.

This account of venturing blindly into uncharted territory and retracing steps resonates with evidence from other eminent creators. As Einstein once said, "If we knew what we were doing, we wouldn't call it research."

To see superfluity and backtracking in practice, consider the sketches that Pablo Picasso produced in preparation for his 1937 *Guernica* painting. Among them are clearly "superfluous" sketches, which have a human head on a bull's body (for example, sketches 19 and 22—using Picasso's original numbering—on the opposite page). Picasso soon discovered that this was a dead end and backtracked to an earlier bull's head drawing (15), before continuing to the final two sketches (26 and 27). Notice that the artist went too far in one direction in the last sketch, from which he backtracked yet again. Even more telling, after that last sketch Picasso largely reversed himself to a much earlier formulation (11), which shares the most unique features with the final version: the widely separated eyes, the thin-lipped open mouth with tongue, the menacing rather than inert visage and the Cubist rather than neoclassic style. These sketches are typical of blind variations both in the arts and in the sciences.

Only further research can expand the theory into a comprehensive, predictive model whose claims can be thoroughly tested. Even so, BVSR can help us make sense of certain quirks of creative geniuses, including their personality traits and developmental experiences. Although they devote considerable time to achieving expertise, they also pursue other hobbies. Their openness to new ideas and their breadth of interests infuse them with seemingly irrelevant stimulation that can enrich blind variations.

As 19th-century German philosopher Arthur Schopenhauer said, "Talent hits a target no one else can hit; genius hits a target no one else can see." Exceptional thinkers, it turns out, stand on common ground when they launch their arrows into the unknown. M

MORE TO EXPLORE

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THE UNLEASHED MIND

HIGHLY CREATIVE PEOPLE OFTEN SEEM WEIRDER THAN THE REST OF US. NOW RESEARCHERS KNOW WHY

By Shelley Carson

He is one of the world's best known and most successful entrepreneurs, with hundreds of patents to his name—including the Segway scooter. But you will never see Dean Kamen in a suit and tie: the eccentric inventor dresses almost exclusively in denim. He spent five years in college before dropping out, does not take vacations and has never married. Kamen presides (along with his Ministers of Ice Cream, Brunch and Nepotism) over the Connecticut island kingdom of North Dumpling, which has "seceded" from the U.S. and dispenses its own currency in units of pi. Visitors are issued a visa form that includes spaces on which to note identifying marks on both their face and buttocks.

Kamen, who works tirelessly at inspiring kids to pursue careers in science and engineering, is one of many highly creative people whose personal behavior sometimes strikes others as odd. Albert Einstein picked up cigarette butts off the street to get tobacco for his pipe; Howard Hughes spent entire days on a chair in the middle of the supposedly germ-free zone of his Beverly Hills Hotel suite; composer Robert Schumann believed that his musical compositions were dictated to him by Beethoven and other deceased luminaries from their tombs; and Charles Dickens is said to have fended off imaginary urchins with his umbrella as he walked the streets of London. In more recent history, we saw Michael Jackson's preoccupation with plastic surgery, Salvador Dalí's affection for dangerous pets and singer Lady Gaga wearing a "meat dress" at a music awards show.

FAST FACTS

OPENING THE MIND

❶ People who are highly creative often have odd thoughts and behaviors—and vice versa.

❷ Both creativity and eccentricity may be the result of genetic variations that increase cognitive disinhibition—the brain's failure to filter out extraneous information.

❸ When unfiltered information reaches conscious awareness in the brains of people who are highly intelligent and can process this information without being overwhelmed, it may lead to exceptional insights and sensations.

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It isn't just average Joes who perceive highly creative individuals as eccentric. These individuals often see themselves as different and unable to fit in. Findings in brain imaging, creativity research and molecular biology suggest that these perceptions are not just based on a few anecdotal accounts of "weird" scientists and artists. In fact, creativity and eccentricity often go hand in hand, and researchers now believe that both traits may be a result of how the brain filters incoming information. Even in the business world, there is a growing appreciation of the link between creative thinking and unconventional behavior, with increased acceptance of the latter.

Making the Connection

The incidence of strange behavior by highly creative individuals seems too extensive to be the result of mere coincidence. As far back as ancient Greece, both Plato and Aristotle made comments about the peculiar behavior of poets and playwrights. (Aristotle was also the first to note the relation between creativity and depression, an association that has also been suggested by modern research.) More than a century ago Italian criminologist Cesare Lombroso catalogued the bizarre behavior of creative luminaries in his book *The Man of Genius* and attributed this behavior to the same hereditary "degeneration" that marked violent criminals.

In the past few decades psychologists and other scientists have explored the connection using empirically validated measures of both creativity and eccentricity. To measure creativity, researchers may look at an individual's record of creative achievements, his or her involvement in creative activities or ability to think creatively (for example, to come up with new uses for ordinary household items). To measure eccentricity, researchers often use scales that assess schizotypal personality.

Schizotypal personality can appear in a variety of forms, including magical thinking (fanciful ideas or paranormal beliefs, such as Schumann's belief that Beethoven channeled music to him from the grave), unusual perceptual experiences (distortions in perception, such as Dickens's belief that he was being followed by characters from his novels), social anhedonia (a preference for solitary activities—Emily Dickinson, Nikola Tesla and Isaac Newton, for example, favored work over socializing), and mild paranoia (unfounded feelings that people or objects in the environment may pose a threat, such as Hughes's legendary distrust of others).

Schizotypal personality is a milder version of the clinical psychiatric condition called schizotypal personality disorder, which is among a cluster of personality disorders labeled "odd or eccentric" in the American Psychiatric Association's *Diagnostic and Statistical Manual of Mental Disorders*. The schizotypal diagnosis grew out of large epidemiological studies in which researchers noticed that the relatives of individuals diagnosed with schizophrenia were more likely to exhibit odd behaviors and beliefs than relatives of those not afflicted with schizophrenia. Schizotypal people, for instance, may dress in an idiosyncratic style; their speech patterns may be somewhat out of the ordinary; they may respond ineptly in social situations; their emotional responses may be inappropriate; they may believe in supernatural phenomena such as telepathy and omens; and they may be hard to get close to—both physically and emotionally. In short, schizotypal individuals are eccentric.

Not all schizotypal people have a personality disorder, however. They are often very high functioning, talented and intelligent. Many of my students at Harvard University, for example, score far above average on schizotypal scales, as well as on creativity and intelligence measures.

Nature or Nurture?

The first scientific evidence of a connection between schizotypal personality and creativity came from a 1966 study by American behavioral geneticist Leonard Heston. In this classic study, Heston reported that children adopted away from their schizophrenic biological mothers at birth were more likely to pursue creative careers and interests than children adopted away from nonafflicted mothers (thus lending support for Lombroso's theory that the bizarre behaviors that often accompany creativity are inherited).

ECCENTRIC PEOPLE MAY INHERIT THE **UNCONVENTIONAL MODES OF THINKING** AND PERCEIVING ASSOCIATED WITH SCHIZOPHRENIA WITHOUT INHERITING THE DISEASE ITSELF.

Harvard researcher Dennis Kinney and his team replicated Heston's study 40 years later and suggested that schizotypal individuals may inherit the unconventional modes of thinking and perceiving associated with schizophrenia without inheriting the disease itself. In this study, Kinney and his colleagues rated 36 adopted offspring of schizophrenic parents and 36 matched control subjects adopted from nonschizophrenic parents using the Lifetime Creativity Scales. They found that the adopted offspring of schizophrenic individuals who themselves displayed signs of schizotypal personality had higher scores for creativity than the control subjects. The Kinney group also made a new discovery: some of their control subjects who did not have a family history of schizophrenia met the profile for schizotypal personality—and they, too, scored higher for creativity than other control subjects.

Taking the reverse approach, studies by British investigator Daniel Nettle and Australian researchers David Rawlings and Ann Locarnini have confirmed that creative individuals tend to score higher on scales of schizotypal personality than

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BETTMANN/GETTY IMAGES (*Dickinson, Einstein, Dickens and Hughes*); SHAHAR AZRAN *Getty Images (Kamen)*; FREDERICK M. BROWN *Getty Images (Lady Gaga)*; PHIL DENT *Getty Images (Jackson)*; GETTY IMAGES *(Newton)*; PAUL ALMASY *Getty Images (Dalí)*

Known for their quirks as well as their accomplishments (*clockwise from upper left*): Emily Dickinson, Dean Kamen, Albert Einstein, Lady Gaga, Charles Dickens, Michael Jackson, Isaac Newton, Howard Hughes and Salvador Dalí.

less creative individuals. In my research at Harvard, done in part with my colleague Cynthia A. Meyersburg, I have found that study participants who score high in a measure of creative achievement in the arts are more likely to endorse magical thinking—such as belief in telepathic communication, dreams that portend the future, and memories of past lives. These participants are also more likely to attest to unusual perceptual experiences, such as having frequent déjà vu and hearing voices whispering in the wind.

In two reviews of schizotypy and creativity—published in 1989 and 1997, respectively—both Robert Prentky, now a forensic psychologist at Fairleigh Dickinson University, and British researcher J. H. Brod concluded that not only do highly creative people display more of the traits associated with schizotypy but that the combination of creativity and schizotypy tends to run in families, again pointing toward a genetic component.

How could weird thoughts and behaviors enhance a person's ability to think creatively? My research suggests that these manifestations of schizotypal personality in and of themselves do not promote creativity; certain cognitive mechanisms that may underlie eccentricity could also promote creative thinking, however. In my "shared vulnerability" model of how creativity and eccentricity are related, I theorize that one of these underlying mechanisms is a propensity for cognitive disinhibition.

Too Much Information

Cognitive disinhibition is the failure to ignore information that is irrelevant to current goals or to survival. We are all equipped with mental filters that hide most of the processing that goes on in our brain behind the scenes. So many signals come in through our sensory organs, for example, that if we paid attention to all of them we would be overwhelmed. Furthermore, our brain is constantly accessing imagery and memories stored in our mental files to process and decode incoming information. Thanks to cognitive filters, most of this input never reaches conscious awareness.

There are individual differences in how much information we block out, however; both schizotypal individuals and those with schizophrenia have been shown to have reduced functioning of one of these cognitive filters, called latent inhibition (LI). Reduced LI appears to increase the amount of unfiltered stimuli reaching our conscious awareness and is associated with offbeat thoughts and hallucinations. It is easy to see that allowing unfiltered information into consciousness could lead to strange perceptual experiences, such as hearing voices or seeing imaginary people.

Cognitive disinhibition is also likely at the heart of what we think of as the "aha!" experience. During moments of insight, cognitive filters relax momentarily and allow ideas that are on the brain's back burners to leap forward into conscious awareness, in the same way bizarre thoughts surface in the

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REDUCED COGNITIVE FILTERING COULD EXPLAIN THE TENDENCY OF HIGHLY CREATIVE PEOPLE TO FOCUS INTENSELY ON THEIR INNER WORLD AT THE EXPENSE OF SOCIAL AND EVEN SELF-CARE NEEDS.

mind of the psychotic individual. Consider this example from Sylvia Nasar's 1998 book *A Beautiful Mind,* about the late Nobel Prize winner John Nash, who was diagnosed with schizophrenia. When asked why he believed that aliens from outer space were contacting him, he responded: "Because the ideas I had about supernatural beings came to me the same way that my mathematical ideas did. So I took them seriously." (Nash's case illustrates how the cognitive mechanism of the eureka moment is similar to the delusional experience called thought insertion, in which individuals suffering from psychosis believe that outside forces have placed thoughts in their brain. Most people suffering from psychosis or schizophrenia do not produce ideas that are considered creative, however. The ability to use cognitive disinhibition in a creative way depends on the presence of additional cognitive abilities associated with a high level of functioning.)

Reduced cognitive filtering could explain the tendency of highly creative people to focus intensely on the content of their inner world at the expense of social or even self-care needs. (Beethoven, for example, had difficulty tending to his own cleanliness.) When conscious awareness is overpopulated with unusual and unfiltered stimuli, it is difficult *not* to focus attention on that inner universe.

In 2003 Jordan Peterson, now at the University of Toronto, and I reported on research we conducted at Harvard and at Toronto, where we found that highly creative individuals are more likely to display cognitive disinhibition when compared with those who are less creative. In a series of studies, we tested several hundred subjects on a latent inhibition task (a measure of how easily subjects ignore stimuli to which they have already been exposed). We also measured creativity in several different ways, including divergent-thinking tasks (which require a large number of responses or solutions to a problem), openness to experience (the personality trait most highly predictive of creativity), the Creative Personality Scale, and the Creative Achievement Questionnaire (a measure of lifetime creative achievement).

When we looked at high scorers on each of these creative measures, we found that they were more likely to have lower scores on the latent inhibition task (indicating cognitive disinhibition) than were the less creative subjects. We think that the reduction in cognitive inhibition allows more material into conscious awareness that can then be reprocessed and recombined in novel and original ways, resulting in creative ideas.

Brain-imaging and electroencephalographic (EEG) studies support the theory that highly creative individuals tend to experience more cognitive disinhibition than do less creative control groups. Beginning in the late 1970s, researcher Colin

People who score high for creative achievement in the arts are more likely to believe in telepathic communication, dreams that foretell the future, and past lives.

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Martindale of the University of Maine initiated a series of EEG studies related to creativity. He and his colleagues found that highly creative people tend to produce more brain waves in the alpha range (a frequency of eight to 12 hertz, or cycles per second) during creative tasks than do less creative people. Martindale and his group interpreted alpha power as a marker of decreased cortical arousal and defocused attention and suggested that creative people were allowing more information into their conscious awareness during creative work.

Andreas Fink and his group at the University of Graz in Austria, who replicated Martindale's findings in a set of studies, have a different interpretation of the increased alpha waves associated with creativity. They say increased alpha activity indicates that the brain is focusing on internally generated stimuli rather than on the outside world. This interpretation explains the tendency of creative people to focus on their inner life, which is also a sign of schizotypal personality.

Other brain research, published in 2009 by John Kounios of Drexel University and Mark Beeman of Northwestern University, has examined the "aha!" moment in greater detail. Kounios and Beeman had subjects solve word-association problems while their brain patterns were recorded using either functional magnetic resonance imaging or EEG. (For example, think of a word that can form a compound word with all three of the following words: crab, pine, sauce. The answer is "apple.") Subjects signaled the exact moment the answer came to them and whether they had come to the solution through trial and error or in a sudden rush of insight. The results indicate that a period of alpha activity precedes a burst of gamma activity (characterized by brain waves in the bandwidth above 40 Hz) at the moment of insight. Kounios and Beeman surmise that alpha activity focuses attention inward, whereas the gamma burst coincides with the arrival of the solution into conscious awareness.

Another brain-imaging study, done in 2010 by investigators at the Karolinska Institute in Stockholm, suggests the propensity for both creative insights and schizotypal experiences may result from a specific configuration of neurotransmitter receptors in the brain. Using positron-emission tomography, Örjan de Manzano, Fredrik Ullén and their colleagues examined the density of dopamine D2 receptors in the subcortical region of the thalamus in 14 subjects who were tested for divergent-thinking skills. The results indicate that thalamic D2 receptor densities are diminished in subjects with high divergent-thinking abilities, similar to

ARE YOU A CREATIVE ECCENTRIC?

RICHARD MORRELL *Getty Images*

To explore the connection between creativity and eccentricity, researchers often use questionnaires that ask about personal experiences and traits. Answer yes or no to each of these sample questions:

1. Do you often have ideas without knowing where they came from?
2. Do you consider yourself a highly logical person?
3. Do you often think or speak using metaphors?
4. Do you have a broad range of interests?
5. Do you have trouble spending time alone without turning on the TV or other electronic devices?
6. Do you believe in telepathic communication?
7. Have you ever felt the presence of someone in the room with you when you knew you were alone?
8. Do you believe that your dreams may sometimes be previews of future events?
9. Do you believe that certain events or objects are signs that may have been provided to help you make important decisions?
10. Do you believe there may be forces at work in the world that cannot be detected with scientific instruments?
11. Do you often feel like a square peg in a round hole?

Scoring

Count the number of yes answers for questions 1, 3 and 4. Add those to the number of no answers for questions 2 and 5. Higher scores (up to a maximum of 5) are more indicative of creative thinking patterns.

Now count the number of yes answers for questions 6 through 10. Higher scores make it more likely that you have schizotypal personality, which is associated with odd or eccentric behavior.

People who score high on the first five questions also tend to score high on the second set of questions. A yes answer to question 11 is related to both creative thinking and schizotypal personality.

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THE **ASCENDANCY OF INNOVATIVE TECHNOLOGY** AS A KEY FACTOR IN ECONOMIC GROWTH HAS ELEVATED CREATIVITY FROM MERELY A POSITIVE TRAIT TO A HIGHLY SOUGHT-AFTER COMMODITY.

patterns found in schizophrenic subjects in previous studies. The researchers believe that reduced dopamine binding in the thalamus, found in both creative and schizophrenic subjects, may decrease cognitive filtering and allow more information into conscious awareness.

Several studies have linked gene variations that are associated with the neurotransmitter dopamine to both creativity and eccentricity. Hungarian researcher Szabolcs Kéri, who reported in 2009 that highly creative achievers were more likely to have a variant of the *neuregulin 1* gene previously associated with schizophrenia, speculated that this gene variation facilitates cognitive disinhibition. These findings support the theory that cognitive disinhibition may be affected by genetic variations and that it may be one factor that predisposes an individual to both creative thought and eccentricity.

The Importance of Intelligence

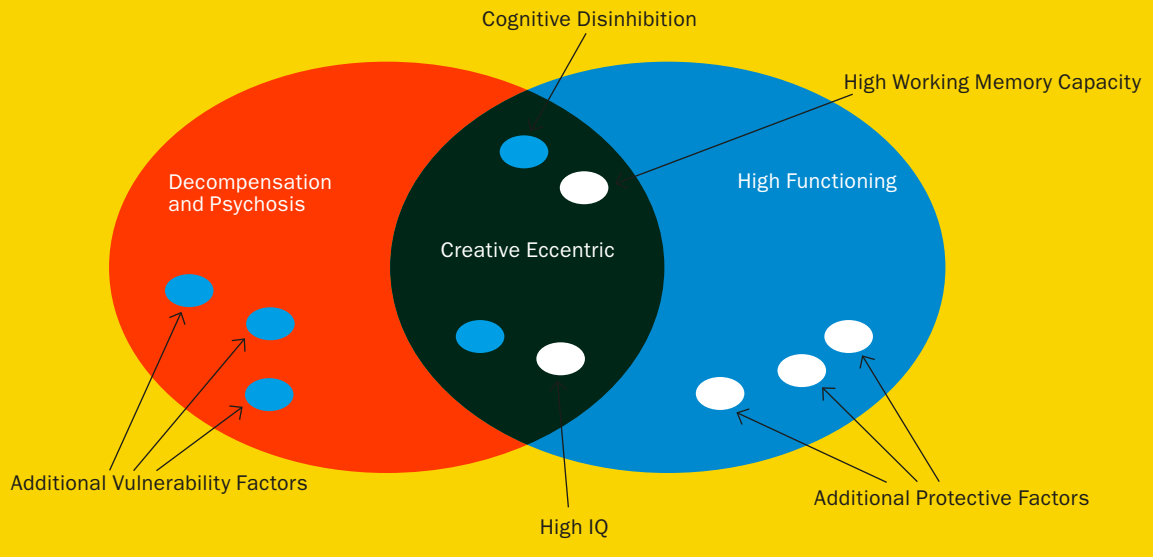
Clearly, however, not all eccentric individuals are creative. Work from our lab indicates that other cognitive factors, such as high IQ and high working memory capacity, enable some people to mentally manipulate extra information without being overwhelmed by it. Through a series of studies, we have, in fact, shown that a combination of lower cognitive inhibition and higher IQ is associated with higher scores for creativity.

The shared vulnerability model suggests that at least a subgroup of highly creative individuals may share some (but not all) biological vulnerability factors with individuals who suffer from psychotic illnesses, such as schizophrenia. This vulnerability may allow the highly creative person access to ideas and thoughts that are inaccessible to those of us with less porous mental filters.

One question I have included in my creativity research asks "Do you often feel like a square peg in a round hole?" Participants who score high on the Creative Achievement Questionnaire have answered yes significantly more often than those who have low scores in creative achievement. In fact, one participant—a Hollywood screenwriter—answered no but then wrote below the question: "I don't feel like a square peg trying

THE SHARED VULNERABILITY MODEL

In the author's model of why creativity and eccentricity often coincide, the oval at the left represents people whose biological vulnerability factors (gene variations, for example) impair their ability to filter out unusual thoughts and may (given enough of these vulnerabilities) even cause psychotic illnesses. The oval at the right represents high-functioning people, whose biological makeup helps to protect them from mental illnesses. At the intersection of these two groups lie creative eccentrics, whose high IQ and high working memory capacity help to shield them from being overwhelmed by a flood of bizarre thoughts and sensations and instead allow them to use those stimuli as inspiration for great works of art and science.



SCIENTIFIC AMERICAN MIND

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Training programs can help stimulate creative thinking.

to fit into a round hole. I feel like an octagonal peg with conical appendages."

The good news is that the plight of square pegs may be improving. The ascendancy of innovative technology as a key factor in economic growth has elevated creativity from merely a positive trait to a highly sought-after commodity in the global market. Many leading corporations—such as Coca Cola, Avis, Citi and Humana—now have chief innovation officers on their leadership teams. Prestigious business schools—such as Harvard, Stanford, Columbia and Yale—have added courses on creativity to their curricula. And Fortune 500 companies, including PepsiCo, Bristol-Meyers Squibb, Aetna and Marriott, now routinely put employees through creativity training programs. Trainers in these classes use a variety of tools and techniques to help noneccentrics open their minds to "out of the box" thoughts and stimuli that might otherwise be ignored or suppressed.

As the market value of creative thinking increases, the round-hole world may continue to make adjustments to accommodate and assimilate eccentrics. Such accommodations already exist in communities with high concentrations of artists, writers, scientists and computer geeks. Managers within these communities tolerate bizarre clothing choices, disregard of normal social protocols and nontraditional work schedules in the interest of promoting innovation. At Dean Kamen's company, Deka Research and Development, for example, not only is denim well accepted, but employees are allowed—even expected—to solve problems and complete tasks in whatever way works best for them.

Square pegs (and octagonal pegs with conical appendages) no longer have to work so hard at fitting in. It is high time. Indeed, we all owe a deep debt of gratitude to those whose creative work has been accomplished at the expense of square-peg feelings of alienation and ostracism. The creative efforts of eccentrics add richness, beauty and innovation to the lives of those of us who have fit somewhat more comfortably into our round holes. M

GETTY IMAGES

MORE TO EXPLORE

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CHARLES J. LIMB: INNER SPARKS

THE HEARING SPECIALIST AND SAX PLAYER SAYS THAT STUDYING THE BRAIN DURING FLIGHTS OF IMPROVISATION MAY PROVIDE NEW UNDERSTANDING OF CREATIVITY—AS WELL AS INSIGHT INTO THE MUSICAL GENIUS OF JOHN COLTRANE

By Alicia Anstead

FAST FACTS
MUSICAL CREATIVITY

❶ Surgeon and saxophone player Charles J. Limb studies the creative process by taking pictures of the brains of jazz musicians while they are making music.

❷ Limb's studies show that creativity is a whole-brain activity that is deeply related to our sense of self.

❸ Understanding how creativity affects reward mechanisms in the brain could help teachers encourage children to be more creative.

Charles J. Limb could have been a professional jazz saxophonist. He grew up in a musical family and showed early signs of talent. He idolized John Coltrane and, as a student at Harvard University, directed a jazz band. Although he ultimately went to medical school, he chose his specialty (otolaryngology) in part because of his musical interest. As a hearing specialist and surgeon at Johns Hopkins Hospital, he performed cochlear implants in patients to restore hearing and enable the deaf to appreciate music. His sensibility and passion as an artist continue to inform his research. At least half of his research efforts during the past decade or so have focused on regions of the brain activated during moments of deep creativity. As he puts it, he wants to understand what went on in Coltrane's head when he performed brilliant improv on his sax night after night.

Limb, now a professor at the University of California, San Francisco, and National Institutes of Health neurologist Allen R. Braun developed a method for studying the brains of highly skilled jazz musicians while they are creating music. Subjects play on a nonmagnetic keyboard as they lie in a functional magnetic resonance imaging (fMRI) machine that takes pictures of their brain. Then the scientists compare neural activity during improvisation with what happens when playing a memorized piece. Limb can also interact with the musician in the scanner by playing on an external keyboard—or, as musicians put it, exchanging riffs.

Excerpts from an interview with Limb when he was at Johns Hopkins follow.

Why should scientists study creativity?

While I think creativity is amazing, I don't put it on a pedestal. I view it as a very normal biological process that some people are able to take to extremely profound levels but that fundamentally is a basic requirement of human civilization and how we advance. It infiltrates every aspect of human life. I don't know that there's an attribute that is more responsible for how we've evolved as a species than creativity.

From a scientific perspective: if it's a biological behavior, if humans are creative beings, we really ought to study it like you study any other complex biological behavior. Furthermore, because it does seem to be important, not just for the arts but for life, it's probably something we should understand better.

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STEPHEN VOSS *Redux Pictures*

Why is improvisation an ideal activity for studying creativity?

There are a lot of forms of creativity. For scientific study, what you really need is the behavior that is a prototypical creative act, realizing that it doesn't represent all creative behavior. Writing a novel is a creative act, but it's hard to do that in an fMRI scanner, and something that takes a year or so to do is hard to study. Musical improvisation is spontaneous. The timescale is relatively concise, meaning that every time you do it, you can constrain it to a time frame quite reasonably and expect artistically relevant results. That's a natural task for a musician. So the timescale is natural for a scientific experiment.

What kinds of challenges did you face in trying to summon creativity on demand? Musicians don't usually find a muse in a science lab.

The musicians were a self-selected bunch. I didn't coerce them to participate. They were all into the idea. The experience is foreign for the first minute or two, and then it becomes surprising-

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ly comfortable. You're in a tube, and it's dark, and you have only headphones—it is almost like a sensory deprivation chamber where the only thing you are doing is playing piano. It's really a strange environment for playing piano, but there's not a lot to distract you. In fact, I think the music is very comforting in that setting because it's the one normal thing about the setting. The sound quality of the piano we used isn't the best. It's noisy as heck in that room. But none of the musicians complained, and they were able to play pretty well. Sometimes musicians felt embarrassed that they weren't able to play the way they usually play, but from my perspective they played very well.

Tell us about the keyboard you used in your experiments and how you adapted it to work with fMRI.

The main issues to do this are ergonomic and magnetic. You have to have a keyboard that works when you are in a narrow tube, on your back. I went into the scanner myself many times and thought about what would be the best way to make this work out. We decided the piano should be on your lap, with your hands at a natural angle in front of you, but your eyes—because you are lying down—could not be looking down. We used mirrors, so you look up at one mirror that points to another mirror that is pointed at the keyboard. In the end, you are looking at your hands even though you are looking straight ahead.

The dimension of the tube is such that we could have only 35 keys. I wanted to make them full size so the players would feel relatively natural. I was working with an engineer who designs MRI-compatible devices, and he and I shipped this device across the country probably 10 times to tweak it. It was a two-year process. What we had to design was a MIDI keyboard—for musical instrument digital interface—so the piano makes no noise. Every time you press a note, it sends a digital message to a computer saying a certain note was pressed. I used a program called Logic Pro, which has a piano emulator. When you press a certain note, the computer program plays the note back through headphones. When you're doing it, it feels very much like you're playing a piano naturally.

What happens neurologically to the brain during creativity?

As far as my studies have revealed, creativity is a whole-brain activity. When you're doing something that's creative, you're engaging all aspects of your brain. During improvisation, the prefrontal cortex of the brain undergoes an interesting shift in activity, in which a broad area called the lateral prefrontal region shuts down, essentially so you have a significant inhibition of your prefrontal cortex. These areas are involved in conscious self-monitoring, self-inhibition, and evaluation of the rightness and wrongness of actions you're about to implement. In the meantime, we saw another area of the prefrontal cortex—the medial prefrontal cortex—turn on. This is the focal area of the brain that's involved in self-expression and autobiographical narrative. It's part of what is known as a default network. It has to do with sense of self.

What implications does your work have for, say, education?

If we can understand what actually changes in the brain to perhaps reduce conscious self-monitoring—what a lot of expert musicians are doing and what amateur musicians are unable to do—that's a pretty interesting target for someone to consider when trying to learn to become an improviser. I think that has implications for describing what gives rise to excellent improvisation and what experts do naturally. How a teacher can take that and utilize it in a lesson is another thing entirely, but I think there's food for thought.

A number of researchers are investigating creativity right now.

Why do you think this convergence of interest is taking place?

We have some new methods of analyzing brain activity and brain function that are allowing us to ask questions that were probably off-limits for scientists. And I think that says a lot about the way scientists are in general. Scientists are, for the most part, a pretty conservative bunch. They're not the kinds that want to answer the riskiest questions in terms of art. There are too many variables, it's hard to explain, and there's not a lot of grant funding. It's not disease-based, etcetera. Now we are seeing that, okay, these are legitimate questions to ask, and we have legitimate methods to try to answer the questions. We need to learn how creativity affects the brain and how to implement creativity in educational systems, how to encourage children to be creative.

How do you respond to skeptics and critics who call fMRI research high-tech phrenology?

That's an interesting criticism. There's a big difference between saying that the scalp is shaped a certain way and saying that an area of the brain is physiologically active. What we're really trying to do is take a glimpse into an artist's brain while he is doing something that is unique. Keep in mind the method we use for this—fMRI—is a very, very inferential method. It is completely imprecise on so many levels, and at best you are inferring a pattern of activity that is associated with a pattern of behavior. Every method has its intrinsic limits, and that's how it should be. And in the end, what you want or hope for is that a lot of different methods, not just fMRI,

THE AUTHOR

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are applied to the same question so that you can see converging data.

There is a reason why we are using fMRI, however. It shows us a lot of things that we've never been able to actually see before, which is human behavior in its most complex forms happening in real time. But I'm a very big critic of anyone who thinks fMRI holds the answer to everything. Having used it, I know it doesn't. On the other hand, that doesn't mean that we shouldn't extract what we can. I mean, it's a cool method.

What are the implications of your creativity research for your work as a surgeon and for cochlear implants?

In truth, the reason why I do what I do is because I love music. That is why I wanted to become a hearing specialist. That led me to treat surgical disorders of hearing primarily. Cochlear implantation is probably the best treatment that has ever existed for a profound sensory impairment, meaning that there is no other sense that can be restored right now like hearing can be with a cochlear implant. These things are amazing technologically. Yet they're also very limited. What they are amazing at is producing language for people who have had intact hearing for most of their lives or for people who are born deaf and gain hearing through implants.

But music is another piece entirely. Most people who have a cochlear implant just cannot hear music well. A large portion of my research goes toward trying to understand the limitations of music perception in deaf people who are hearing with a cochlear implant. And I am hoping to try to improve that. So that is a large part of what I study as well.

For me, the two parts of my work are motivated by the same idea of bringing the sublime to the deaf. The idea of going from deaf to Beethoven's Symphony no. 9 is pretty remarkable. I would love to be able to take somebody there.

What's next in your creativity research?

The "trading fours" research, in which I exchange riffs with a musician in the scanner, is still ongoing, as are the studies of freestyle rappers, which I believe represents the first-ever neuroscientific study of hip-hop.

The next real direction I've headed into has to do with trying to clarify our study of reward mechanisms in the brain and their relation to creativity. Why is it that we like to be creative? Why is it that we like to perceive creativity? And what happens when somebody is improvising in terms of pleasure or reward centers? Where is the gratification neurologically, and how does that change according to the emotional content of the music?

I've always wondered: Why do we love sad music? Why does it make us feel better and not worse? It's a funny inversion that takes place in the brain. Whereas we try to avoid sadness in life, in art, and especially in music, we almost gravitate toward it. By and large, the effect is very positive. Improvisation causes a similar response: When you're spontaneously creating music that is sad, what are you getting? Are you getting joy? Pleasure? What's the basis of the reward? That's one of the directions I'm heading.

What's your best answer to how Coltrane continually improvised masterpiece after masterpiece on his saxophone?

My best answer, honestly, is that he practiced. He was an obsessive—he practiced obsessively, even after a gig. He would play a gig and then go back to his hotel room and practice. And he was, I think, obsessed with an idea that was well beyond a performance, well beyond what a critic or a listener thought. He was really after some sort of musical perfection: the ability to have an idea that he had never had before, have that idea be profound and, at the same time, be able to execute that idea. That's a remarkable trio of goals to have right there. I think he knew that the only way he would even come close was to keep that horn in his mouth. M

COURTESY OF CHARLES J. LIMB

Keys to creativity may emerge from imaging musicians' brains.

MORE TO EXPLORE

- A current biography of Charles J. Limb and a list of selected publications on his University of California, San Francisco, Web site: **profiles.ucsf.edu/charles.limb**
- Limb's much noted "Your Brain on Improv" presentation at a TED conference: **www.ted.com/talks/charles_limb_your_brain_on_improv.html**
- Watch a video of Limb and his work: **www.scientificamerican.com/article/anstead-limb-your-brain-on-jazz**

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BRIAN WILSON: A CORK ON THE OCEAN

THE RISE AND FALL OF THE BEACH BOYS LEADER SHOWS HOW CRUCIAL THE BRAIN'S EXECUTIVE FUNCTION IS TO CREATIVITY

By Brian Levine

FAST FACTS

LOST AND FOUND

❶ Singer and composer Brian Wilson achieved tremendous success with the Beach Boys, but the mental illness that may have initially contributed to his visionary inventiveness later became debilitating.

❷ Mental illness can break down the brain's executive function—the ability to plan and carry out the steps required to accomplish a goal.

❸ Wilson's comeback shows that treatment can make it possible to recover from mental illness and regain a measure of lost creativity.

What differentiates mere talent from creative genius? No one knows for sure. We do know, however, that many artistic advances and scientific discoveries come from men and women in their 20s—just old enough to have sufficient technical skills yet young enough to be unencumbered by the habits of older generations.

Psychological studies also indicate that highly creative people share an elevated risk of serious mental illness. For certain individuals, such ailments may actually contribute to their soaring achievements. Yet often the same condition eventually ruins their inventiveness and their life. Perhaps no story better exemplifies how mental illness can free up creativity, then crush it, than that of Brian Wilson.

By age 22 Wilson had already invented a new form of American folk music, achieving tremendous success with his group, the Beach Boys. From 1962 to 1965 the Beach Boys had 16 top-40 hits, including "Surfin' USA," "Little Deuce Coupe" and "I Get Around." Wilson, the group's primary writer, arranger and producer, then expanded his musical landscape with the Beach Boys' 1966 record *Pet Sounds*. The album altered the course of modern pop with its novel studio techniques, complex harmonic and rhythmic structures drawn from jazz and classical music, unusual instru-

MARTIN SCHOELLER *August*

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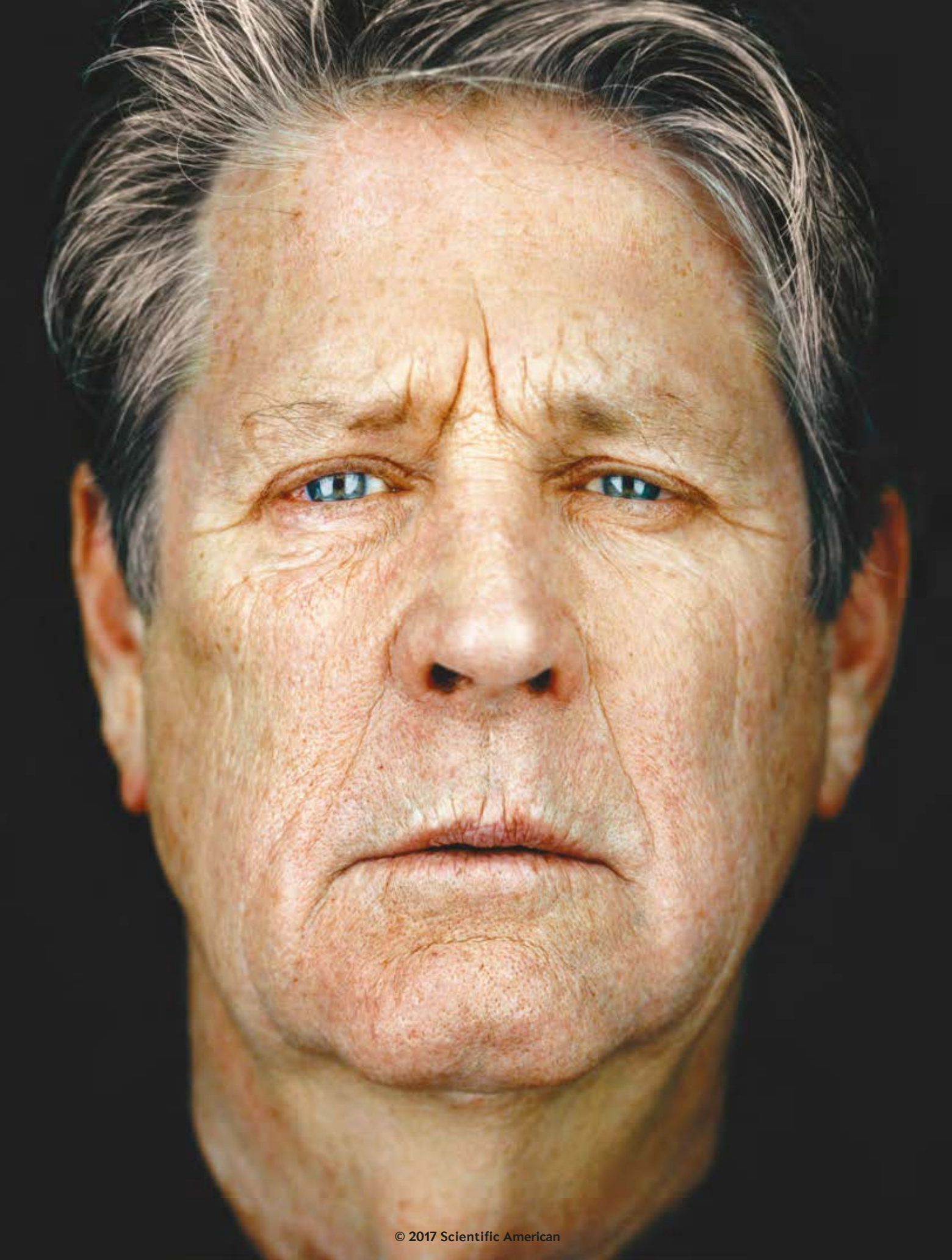

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Brian Wilson (*at left*) was the primary writer, arranger and producer for the Beach Boys, who by 1965 had more than a dozen top hits, such as "Surfin' USA" and "I Get Around."

mentation, and substantive themes of introspection and vulnerability. The legendary conductor and composer Leonard Bernstein called Wilson one of the greatest composers of the 20th century, and Paul McCartney of the Beatles cited *Pet Sounds* as the major influence for the group's own inventive landmark album in 1967, *Sgt. Pepper's Lonely Hearts Club Band*.

Unfortunately, the importance of Wilson's work was soon overshadowed in the popular consciousness by his steady and very public mental decline. In his early 20s, the typical age of onset for many psychotic disorders, social discomfort, depression and paranoia gave way to frank hallucinations and delusions. Over the following decade his condition progressed, and for a period of years he was unable to function consistently as a member of society, much less at his previous level as a hit-record producer.

Progressive mental illness such as that experienced by Wilson causes a breakdown in "executive function"—the ability of the brain's frontal lobes to plan, coordinate and execute, much the way a CEO would direct the operations of a business. Cognitive neuroscientists are still debating the definition of executive function and its influence on behavior. But Wilson's case provides powerful evidence of its sway. Thirty years after his decline, Wilson reemerged as a healthier individual and returned to making music. His incredible story shows how executive function can set creativity free, how its demise can subsequently cripple that creativity

THIS PAGE AND OPPOSITE: MICHAEL OCHS ARCHIVES *Getty Images*

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and the ability to negotiate daily life, and how proper treatment and support by psychiatrists and loved ones can create ways to compensate—in Wilson's case, allowing him to make a comeback.

"'Til I Die"

Neuroscientists maintain that the frontal lobes mediate a collection of high-level cognitive processes that enable us to control and direct lower-level processes. These executive functions allow us to transform a jumbled heap of puzzle pieces into a coherent picture. Think about preparing to go on a major trip. Your brain's CEO, working from the frontal lobes, sequences and prioritizes the many steps that must be performed, generating a plan to accomplish your goal and coming up with new tactics when circumstances change [*see box on page 45*].

Because the frontal lobes interact with multiple brain systems, executive functions are highly sensitive to brain disease, psychiatric disorders and substance abuse. Despite their central role and vulnerabilities, however, executive functions are not as well understood or appreciated as other mental capacities, such as memory and perception, which are more easily assessed in the lab. And because demands for executive functions are greatest in unstructured, novel situations, patients with executive difficulties often appear normal when taking routine psychological and neurological tests. Executive dysfunction is therefore often not diagnosed, even in people who are seriously disabled by it.

The creative innovations heard on *Pet Sounds* coincided with the onset of Wilson's psychosis, which is characterized by a loosening of linkages between ideas. (This article is based on publicly available information, such as the authoritative books *The Beach Boys*, by David Leaf, and *The Nearest Faraway Place: Brian Wilson, the Beach Boys, and the Southern California Experience*, by Timothy White; documentaries such as an episode of A&E's *Biography* series; media interviews with Wilson himself—notably *Larry King Live* in

CERTAIN MENTAL ILLNESSES CAN ACTUALLY CONTRIBUTE TO ARTISTIC ACHIEVEMENTS BUT EVENTUALLY RUIN LIVES.

A young Wilson, shown here in 1966, held in his mind intricate arrangements of many instruments and vocal harmonies, instructed older musicians to perform each part in the studio, then wove them together electronically, a masterful feat of executive function.

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EXECUTIVE FUNCTIONS ARE HIGHLY SENSITIVE TO BRAIN DISEASE, PSYCHIATRIC DISORDERS AND SUBSTANCE ABUSE.

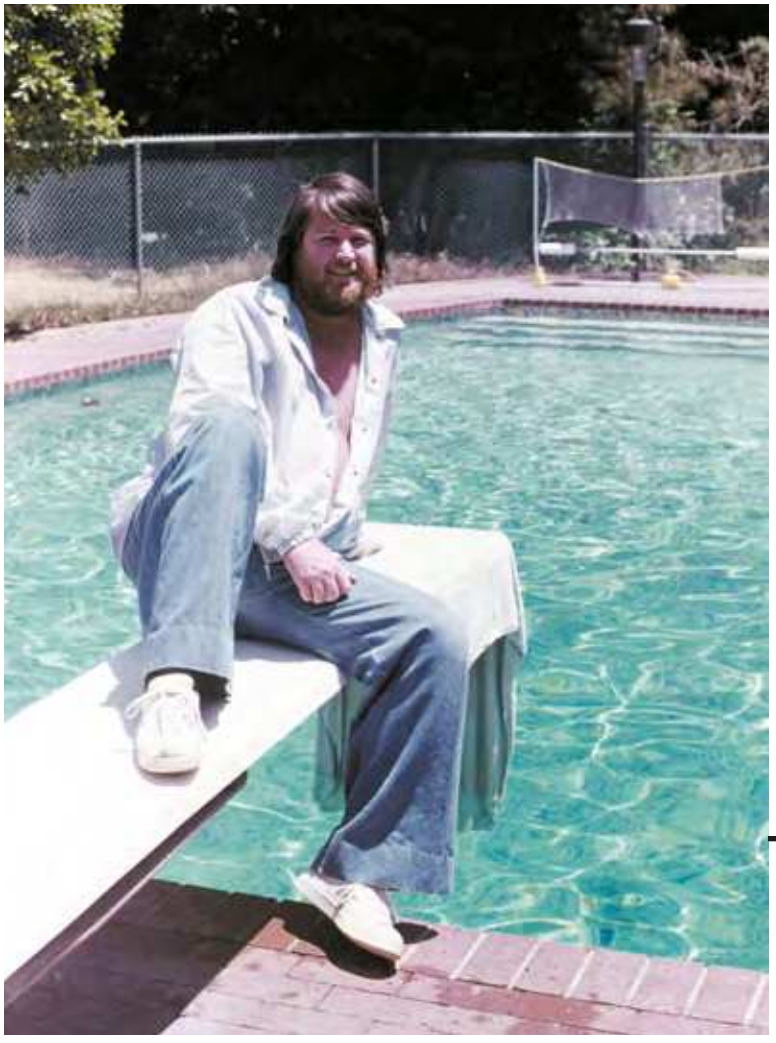
2004—as well as other sources. I have not talked to Wilson, nor have I seen his medical records, but the many sources converge on a description that experts would recognize as psychosis.)

Mental illness does not make a person creative. But certain individuals who are endowed with artistic vision and particular technical skills can, at times, transform the loosening of linkages into inspired artistic associations. These novel associations can be difficult for the individual to harness, however, because a person with psychosis is betrayed by his own disordered perceptions. It is a frighteningly lonely disease, which Wilson perhaps knowingly portrayed in 1971 when he wrote "'Til I Die." The song's lush music, reminiscent of the sea, stands in stark juxtaposition to the lyrics: "I'm a cork on the ocean / Floating over the raging sea.... I'm a leaf on a windy day / Pretty soon I'll be blown away...."

Wilson had reached a breaking point in late 1964 on a plane flight to Houston, when he suffered a nervous breakdown. He subsequently stopped touring with the Beach Boys so that he could focus his attention on writing and studio work for the band, avoiding the stress of the road. He used the Wrecking Crew for the instrumental recording sessions, the same studio musicians employed by his idol, Phil Spector, who defined the role of the modern record producer with hits by the Crystals and the Ronettes, such as "Da Doo Ron Ron." Wilson's new work, appearing in 1965 on the next two albums, *The Beach Boys Today!* and *Summer Days (and Summer Nights!!),* introduced elements that later came together in fully realized form on the *Pet Sounds* album.

To create *Pet Sounds,* Wilson enlisted a new collaborator, Tony Asher, to assist with lyrics intended to depart from the previous themes of surfing, girls and cars. Wilson constructed songs at the piano, beginning with "feels," or fragments of music representing a certain mood. By the time he entered the recording studio, he had a full arrangement in his mind that he then deconstructed by teaching musicians their parts one instrument at a time—from strings, horns and accordions to a water jug, bicycle bells and the theremin, the electronic gizmo responsible for spooky sounds in old horror movies and later made famous in the Beach Boys' song "Good Vibrations." Indeed, Wilson often demonstrated the parts himself because he could play nearly all the instruments. Outtake recordings of Wilson working in the studio (which were included in the 1996 *Pet Sounds Sessions* box set) give an impression of a 23-year-old visionary leader directing the older and more experienced studio musicians to realize his artistic vision.

The last elements to be laid down on the album



Once psychosis took root, Wilson had only intervals of creativity; his weight ballooned, he seldom performed, and he confined himself to his bed for long periods.

MICHAEL OCHS ARCHIVES Getty Images

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THE BRAIN'S "CEO"

The role of executive function in human behavior is to coordinate the many brain activities needed to set goals, make plans to attain those goals, organize steps to carry out those plans, and ensure that the desired outcomes are achieved. This capacity can be likened to that of a company's chief executive officer. Psychologists are not in full agreement, but most acknowledge that multiple executive functions are mediated by the frontal lobes. The ones described below are engaged often.

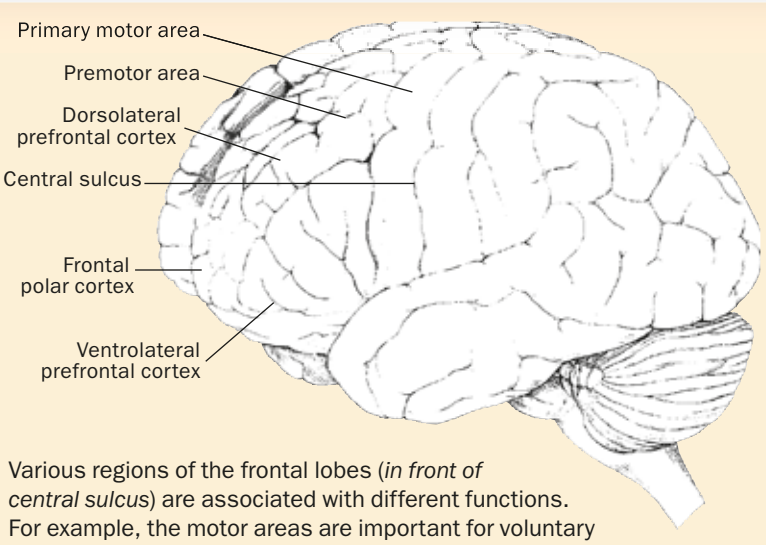
Abstract thinking. Discerning relations among stimuli—seeing the forest for the trees—depends on abstract thinking. Imagine being asked to group into two sets of objects a pair of scissors, a water glass, an ax and a wheelbarrow. You might decide that the scissors and the water glass go together because they are used indoors, whereas the ax and wheelbarrow are used outdoors.

Attention shifting. Can you find another grouping? Scissors and axes cut; glasses and wheelbarrows contain. Many people with executive deficits find it hard to shift attention and inflexibly hold on to their original perceptions and behaviors, even when the usefulness of these associations has long expired.

Information manipulation. Nearly all higher-order cognitive operations require the real-time manipulation of information held in short-term memory. To prepare for a dinner party, a host has to juggle multiple timetables of when different foods will be cooked as well as consider the likes and dislikes of guests.

Planning and foresight. Preparing for a vacation requires foresight and analysis of the conditions and needs at the destination, which may be very different from the conditions and needs at home. A patient with executive dysfunction is often unable to escape the present to form a mental model of a future that is different.

Monitoring and error correction. These processes are engaged when results do not correspond with intentions. This effect could be seen, for example, in a woman who drives to a special bakery to buy a pie for a dinner party she is throwing that evening and finds it is closed. She might go to another bakery on the other side of town without considering that the trip would not allow her to get back home until long after the guests had arrived.



Various regions of the frontal lobes (*in front of central sulcus*) are associated with different functions. For example, the motor areas are important for voluntary movement. The prefrontal cortex mediates executive functions.

Decision making. Consider a man who is having trouble making ends meet. He could cut expenses or increase income, either path requiring him to weigh options, arrive at a decision and see it through. Patients with executive difficulties cannot settle on a choice, particularly in situations where the correct response is not obvious or previously learned. They may blindly follow other people's suggestions, which is why they can be easily exploited.

Inhibition. Automatic responses can be unhelpful or even harmful. Imagine you have just won a major award; your reaction would be to tell everyone your news. But waiting until other finalists are properly informed of their loss requires inhibition.

Social functioning. Failure to appropriately process or output social cues can have devastating consequences. The main concern of one frontal lobe dementia patient, on seeing that his wife was cut and bleeding badly from an accident involving a power tool, was that the tool be cleaned as soon as possible.

—*B.L.*

were the Beach Boys' vocals. No one but Wilson knew how the pieces would fit together until he assembled them at the final stage of production, when something spiritual emerged. As Timothy White, editor in chief of *Billboard* magazine throughout the 1990s, wrote in the liner notes to *Pet Sounds Sessions,* "What shines brightest behind, within and above the peal of Brian's exquisite material is the presence of the thing not named: an unswayable belief in the enduring power of one's better self."

Recording multiple instrumental and vocal tracks and fitting them into a coherent whole relies on manipulating many streams of information held in short-term memory, a key executive function. Whereas other producers at the time recorded relatively simple songs in a single "take" performed by the entire group, Wilson held in his mind intricate symphonic arrangements and harmonies, recorded

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Improved therapy for schizoaffective disorder, along with support from his friends and second wife, Melinda, enabled Wilson to return to active touring after 30 years.

parts separately, then later put together the pieces of the puzzle. "Good Vibrations," dubbed a "pocket symphony" by Wilson and released as a single just after *Pet Sounds,* was recorded in 17 sessions at various studios. The hit, which in music polls ranks as one of the greatest pop songs ever, represented the ultimate marriage of creativity with executive functions, prompting a key transition in popular music in which the studio itself was added to the impresario's quiver.

How was Wilson able to accomplish these monumental feats of vision and concentration while suffering from serious mental illness? Psychotic symptoms are not static; they wax and wane. Wilson's productivity was most likely greatest when his symptoms were in remission—when novel creative associations could be screened, manipulated and coherently integrated by his musical and executive powers.

Two Years in Bed

These powers were soon eclipsed by Wilson's progressive mental illness. The balance between inspiration and the cognitive capacity to realize that inspiration had shifted by 1967, as he and lyricist Van Dyke Parks were putting together *Smile,* an integrated set of album cuts centered on American culture and history.

A good indication of how Wilson's capabilities were slipping involves "output monitoring." This executive function gives someone the ability to compare his actions with his intentions—to screen for errors and bad ideas. Wilson used unusual but successful sound ideas on *Pet Sounds,* such as bicycle bells to invoke themes of lost childhood, but his quest during *Smile* became bizarre—outfitting his musicians with fire hats during the recording of "Mrs. O'Leary's Cow" or infamously placing his piano in a sandbox. Yet because by this time he had been labeled as a "genius," people around him often indulged his eccentricities rather than confronting them as symptoms of serious sickness. Evidence of faulty monitoring can also be heard in the original *Pet Sounds* recording, in which Wilson, usually the consummate perfectionist, allowed background chatter from the studio to creep into the final mix.

Once he had completed *Smile*'s elements, Wilson seemed unable to fit them together. Parks eventually left the project, according to several accounts. Capitol Records was pressuring Wilson to produce something. But emotionally fragile and without support from his bandmates, he scrapped the *Smile* project in mid-1967.

Wilson's mental health steadily deteriorated, with occasional bouts of suicidal depression and psychosis. His drug habit, which could have been an attempt to self-treat his symptoms (common among patients with psychosis), expanded into heroin and especially cocaine use. He demonstrated intervals of creativity, but he never matched the breadth and complexity of his earlier work. He had two young children but was unable to assume a parental role and separated from his wife in 1978. By the early 1980s Wilson's weight had ballooned to more than 300 pounds, and he confined himself to his bed for two and a half years. Although there were periods of hospitalization and detox, treatment was not sustained. Wilson's public appearances were inconsistent at best.

Because of his tremendous notoriety, Wilson's mental troubles soon became part of the public consciousness. The media mocked him as some kind of nut. Viewed from the patient's perspective, however, staying in bed makes perfect sense when one is immersed in a warped reality.

As is often the case with patients who have executive dysfunction, Wilson's compromised state left him vulnerable to exploitation. His own psychologist, the late Eugene Landy, directed his life and career in the mid-1970s and then again from 1983 to 1991, according to several accounts and to Wilson's second wife, Melinda, during the Larry King interview. Although Landy was successful in isolating Wilson from illicit drugs and in helping him to lose weight, he also fostered a dependent

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relationship: he administered psychotropic drugs to Wilson, acted as his business adviser, and even attempted to collaborate with the artist on songwriting and singing. Wilson's family sued for conservatorship in 1990, and the issue was settled the following year. The court severed contact between Wilson and Landy, who had by then already surrendered his license to practice psychology in California to the state's Board of Medical Quality Assurance after conceding that he had unlawfully administered drugs to Wilson.

WILSON'S COMEBACK SHOWS THAT WITH PROPER TREATMENT, A LIFE LOST TO PSYCHOSIS CAN REBOUND.

Creative Prosthesis

Throughout the 1990s Wilson received more conventional treatment, including medication and psychotherapy. He settled into a stable marriage. During the Larry King interview, Wilson and Melinda revealed that he had been diagnosed with schizoaffective disorder, a combination of psychosis and abnormal mood. With support from his wife and musical colleagues, Wilson was reemerging in public, recording albums and performing as a solo artist, accompanied by musicians from the Los Angeles band the Wondermints and former Beach Boys guitarist Jeff Foskett.

Improved treatment of schizoaffective disorder has helped Wilson and many others. After more than 30 years he returned his attention to *Smile,* widely considered one of the greatest unreleased albums in contemporary music. Wilson appeared comfortable in the recording studio—executive dysfunction does not directly compromise memory or acquired musical skills. But it does affect the capacity to flexibly deploy them, particularly in an unstructured situation where there are no clear right or wrong answers, as in the creation of an album.

Wilson released *Smile* in 2004, at age 62, to worldwide acclaim. Its success is attributable to the quality of the original material and to the guidance and support of others who helped Wilson assemble the pieces—people who provide a prosthesis for Wilson's frontal lobes. According to White's book, Wilson had recognized this need as early as 1976, when in a recording session he had said, "Something happened to my concentration—I don't know exactly what, but it weakened for some reason—and I lost the ability to concentrate enough to follow through." Wilson also began appearing live again, sitting in front of a keyboard, although he does not play much. His singing, though still serviceable, can be inconsistent. None of this really matters to his fans, however, who come for Wilson's legend and mystique.

Wilson reached a creative zenith in his early adulthood in spite of (and perhaps partly because of) his mental illness, which eventually robbed him of the cognitive abilities required to create art and nearly destroyed him. Wilson's comeback demonstrates that with proper treatment and support, individuals with mental illness can function at a high level in areas of their expertise, even if their symptoms persist.

During the painful interim, life took down other family members in the Beach Boys. Wilson's brother Dennis, the heart of the band, drowned in 1983, and brother Carl, the guitarist with the angelic voice, died of cancer in 1998. And whereas *Pet Sounds* was so perfectly poised in time, the political, cultural and musical milieu that spawned *Smile* almost immediately became a casualty of violence, war and lost innocence.

To paraphrase renowned psychologist and memory researcher Endel Tulving of the Rotman Research Institute in Toronto, time's arrow runs straight, but memory endows us with the capacity to bend that arrow into a loop, to revise the past in our mind to regain, even if in fantasy, that which was lost. If Wilson's public resurrection bolsters this hope, then *Smile* in 2004, bending time's arrow back 37 years, codifies it. Perhaps, then, *Smile* fulfills a larger purpose beyond its lush and creative music: the need to believe that that which was lost can be regained. M

MORE TO EXPLORE

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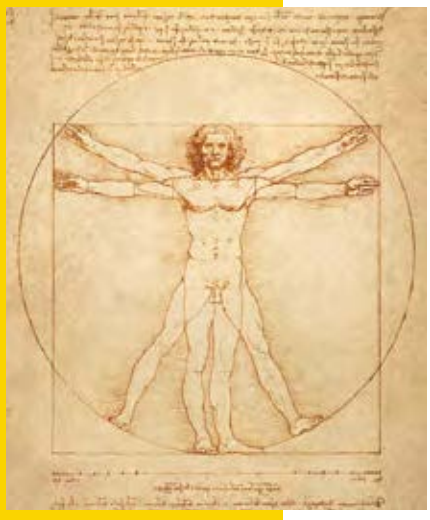

LEONARDO DA VINCI, NEUROSCIENTIST

CREATIVITY MAY BE DEFINED AS PRODUCTIVITY MARKED BY ORIGINALITY. LEONARDO'S STUDIES OF THE BRAIN WERE AS CREATIVE AS HIS ART

By Jonathan Pevsner

FAST FACTS

WINDOW TO THE SOUL

❶ Leonardo da Vinci was not only an accomplished artist, musician, scientist and engineer but also a talented anatomist.

❷ Some of his detailed, beautiful drawings of the skull depict anatomical features that he was the first to identify or accurately render.

❸ Leonardo's extraordinary artistic creativity, coupled with impressive technical skills, helped him to form and test ideas about sensory perception and in particular to investigate the structure and function of the brain.

The archetypal Renaissance man, Leonardo da Vinci is admired for his unequaled range of intellectual passions. The creator of the *Mona Lisa* and other artistic masterpieces in the second half of the 1400s and early 1500s was also an accomplished musician, scientist and engineer whose inventions included ball bearings, instruments to measure the specific gravity of solids, and fantastic war machines (although he abhorred the "most bestial insanity" of battle).

Less well known—largely because hundreds of pages of his notes and detailed anatomical drawings went unpublished until the late 19th and early 20th centuries—are his remarkable and penetrating findings in the field of neuroscience. In an era more comfortable accepting notions handed down from medieval science and ancient Greece and Rome, he pioneered the practice of sketching anatomical features based on his own direct observations. He also strove to establish a physical basis by which the brain interprets sensory stimuli and through which the mind functions. And he developed a coherent theory of how the senses operate, in particular how the eye sees—mechanistic explanations of such phenomena that reflect the

Leonardo da Vinci's studies of physical form (*The Vitruvian Man*) also went below the surface, to structures in the brain. The mirror writing compares the layers of an onion with those of a skull. The depiction of the three oval ventricles is inaccurate but follows the teachings of the time—the artist later broke with such conventions.

GETTY IMAGES

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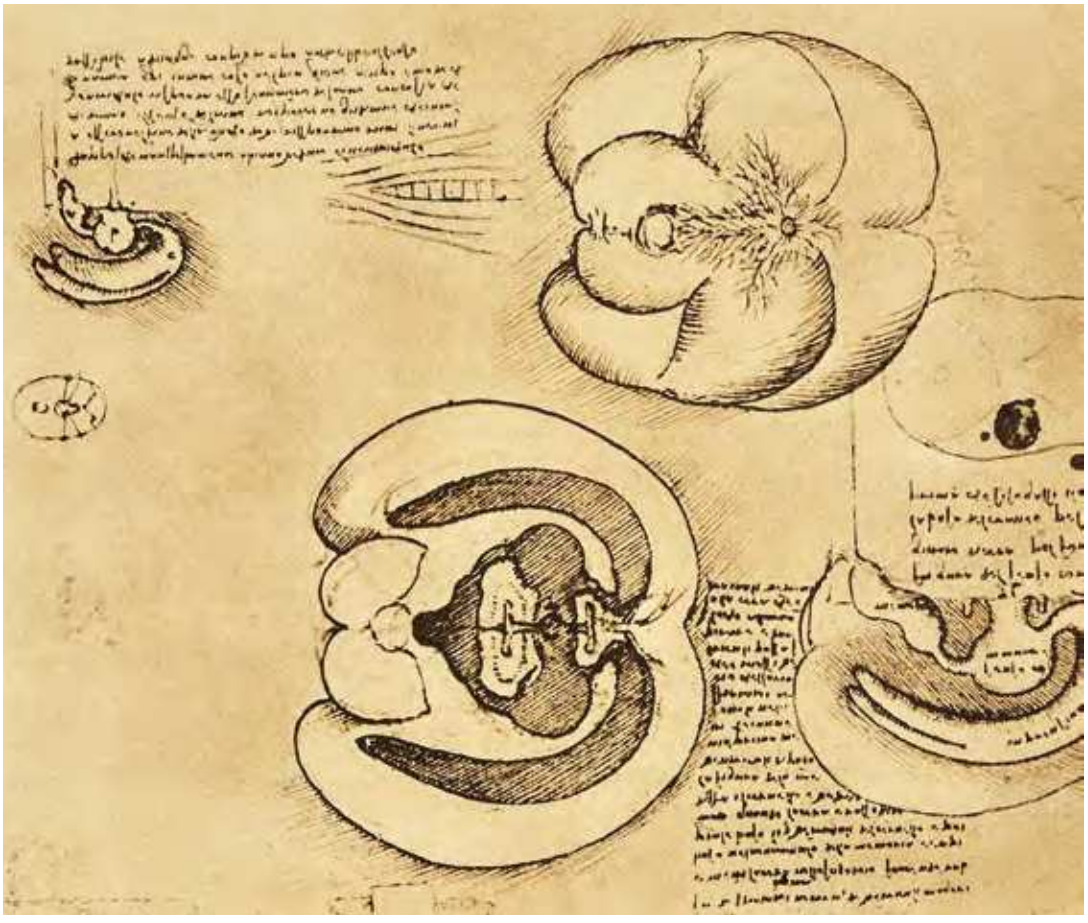

As part of his extensive anatomical explorations, Leonardo injected wax into ox brains to make casts of the ventricles, which he then sketched.

DE AGOSTINI PICTURE LIBRARY *Getty Images*

thinking typical of his primary career, engineering.

Leonardo never went to university and only began studying Latin in his 40s. As he wrote, "my works are the issue of pure and simple experience, which is the one true mistress." As a keen student of nature, Leonardo stands apart from most of his contemporary anatomists, who tended to regurgitate the dogma of earlier Greek and Roman authorities—from the school of Hippocrates to the teachings of Galen of Pergamum. Yet he was not entirely unfettered by his era's reliance on the past. The views common in his day also shaped—and sometimes confounded—his efforts to understand the human brain.

Foundation of Life

Leonardo was born on April 15, 1452, near Vinci, some 20 miles from Florence. As a teenager he joined the workshop of Andrea del Verrocchio in Florence, and at age 20 he was admitted to the Company of Painters. Artists in Renaissance Florence were encouraged to perform, or at least observe, dissections. Leonardo's paintings such as the *St. Jerome,* composed around 1480, indicate that he had gained knowledge of human musculature. But little evidence suggests that he performed autopsies or displayed a deeper interest in anatomy until later in the 1480s, when he moved to Milan. There his relentless curiosity would lead him to a striking series of discoveries in the fields of neuroanatomy and neurophysiology.

Leonardo's earliest surviving anatomical drawings are related to the nervous system and date from circa 1487, when he pithed a frog (pierced its spinal column). He may have been the first person to perform this experiment. He wrote: "The frog instantly dies when its spinal medulla [medulla oblongata] is perforated. And previously it lived without head, without heart or any interior organs, or intestines or skin. Here therefore, it appears, lies the foundation of movement and life." Leonardo loved animals: he was a vegetarian, was known to buy birds at the market to set them free, and was an avid enthusiast of horses. Perhaps for this reason none of the rest of his many hundreds of experiments recorded vivisection.

On the same sheet with the frog, he sketched the spinal cord and added the words "generative power," reflecting the belief, which had originated

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1,900 years earlier with the famed Greek physician Hippocrates, that sperm derive from the spinal cord. Next to the spinal cord, Leonardo drew a tube, with a caption that said that the sense of touch was the cause of motion and the "passage for animal powers" (*transito della virtu anjmalia*).

Leonardo might have been exposed to the ideas of animal spirits through the writings of Galen (roughly around A.D. 130 to 200), the greatest physician of the ancient Roman era. After Galen's death, progress in anatomy stalled for eight centuries, until the rise of Islam. Galen described a concept first developed by a physician from the famous medical center at Alexandria, Erasistratus of Ceos (who flourished circa 300 B.C.). Erasistratus believed that air breathed in is converted to "vital spirit," which is conveyed to the brain's ventricles, where it becomes "animal spirit." This animal spirit filled the hollow nerves and enabled them to control the movement of muscles. (Today we understand that nerve cells are not hollow and that they propagate an electrical signal to the nerve terminal, where chemical neurotransmitters are released across the synapse, a small gap between the neuron and muscle cell. These chemical transmitters induce a muscle cell to contract.)

Turning to Leonardo's early drawings of the brain, we find a remarkable page dated to approximately 1493 [*see illustration on page 49*] showing a cross section of an onion and several drawings of the human head with schematic views of the eye. Beside the images, he wrote: "If you will cut an onion through the middle, you will be able to see and enumerate all the coats or rinds which circularly clothe the center of this onion. Similarly, if you will cut through the middle of the head of a man you will first cut the hairs, then the scalp, then the muscular flesh and pericranium, then the cranium; and inside, the dura mater, the pia mater and the brain; then again the pia mater and dura mater and the rete mirabile and then the bone, their foundation." This text was derived from Ibn Sīnā (also called Avicenna, who lived from A.D. 980 to 1037), a Persian philosopher and physician who grew to prominence comparable to Galen's, largely through his encyclopedic *Qanun fi-al-tibb* (*Canon of Medicine*), one of Leonardo's principal sources.

Leonardo's depiction of the skull includes the frontal sinus, shown as a protrusion just above the eye, which is one of his original discoveries. The optic nerve projects from the eye toward the center of the brain, encountering the first in a row of three oval ventricles—they look quite different from the actual appearance of these cavities filled with cerebrospinal fluid. Leonardo's ventricles also appear in a view from above, which shows the optic and auditory nerves entering the anterior ventricle.

What inspired Leonardo to draw the brain's ventricles this way? Galen had localized cerebral functions, including sensory and motor output, to brain regions near the ventricles. Galen's interpreters subsequently introduced the doctrine of three ventricle "cells," ascribing various brain functions to them. An anterior cell was thought to serve as the common meeting place for all the senses, and hence it was called *sensus communis* in Latin. (Our phrase "common sense" derives from this term.) Most authors placed fantasy and imagination in the *sensus communis* as well. The middle ventricle housed *cogitava, ratio* or *estimativa*—what we call rational thinking. Ibn Sīnā's *Qanun* explained that the *sensus communis* in the anterior ventricle receives sensory information, the imagination holds the sensory perceptions after they have subsided, and the cogitative faculty in the middle ventricle can manipulate images stored in the imagination—creating the idea of a flying man or an emerald mountain, for example. Most authors agreed that the posterior ventricle was the seat of memory.

BECAUSE HE BASED HIS THEORIES OF THE MIND ON PHYSICAL LAWS, HE WAS SOMETIMES LED IN UNEXPECTED DIRECTIONS.

In many dozens of medieval and Renaissance manuscripts, we find diagrams in which the *sensus communis* is depicted in the anterior ventricle, such as Leonardo indicates in the illustration on page 49. But Leonardo modified his views in a dramatic contrast to the prevailing dogma, transferring the *sensus communis* to the middle ventricle and now labeling the anterior ventricle *imprensiva*. The word "*imprensiva*" is difficult to translate, and no anatomist before or after Leonardo has used this term. It refers to a site for the processing of sensory impressions, in particular visual input. Thus, he continued to show the optic nerve terminating in the anterior ventricle. The olfactory and auditory nerves entered the middle ventricle, which was labeled *senso comune* (Leonardo's Italian term for *sensus communis*) or sometimes *comocio* (thought) or *volonto* (will).

Leonardo's unique labeling of the ventricles reflects the tremendous importance he accorded to the sense of vision, which he described as the window to the soul and the most important basis of all experience. To him, the role of the artist was to depict

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nature—"the painter's mind must of necessity enter into nature's mind in order to act as an interpreter between nature and art"—and this role primarily involves vision. Unlike any other artist or anatomist, Leonardo equated artistic perception with an anatomical framework for seeing. He believed that once information passed to the *senso comune* it was judged, and he thought of this function as an inner eye, or *occhio tenebroso* ("the eye in shadows").

Between 1487 and 1493 Leonardo created a number of marvelous drawings of the skull. These beautiful, lifelike images are among his most inspired anatomical works. In one [*see illustration below*], we see a skull divided down the middle, allowing a view of multiple depths. On the left side is the maxillary antrum, a cavity in the facial area, which Leonardo was the first to identify. The accompanying text concerns the location of the *senso comune* relative to the face, as well as a discussion of the number of teeth. (Leonardo corrected Aristotle, who had suggested that men have more teeth than women.)

Another anatomical tour de force [*see illustration on opposite page*] provides the first accurate

Split view of the skull shows the maxillary antrum, a cavity in the facial area that was discovered by Leonardo.

GRAPHICAARTIS *Getty Images*

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Drawing shows the first accurate depiction of the meningeal arteries, which supply blood to the brain. It also shows cranial nerves converging within the brain's center—an idealized, not actual, location.

depiction of the meningeal arteries; the blood supply to the brain was significant to Leonardo as the source of "vital spirit" to the ventricles. This diagram also shows the cranial nerves leading to the geometric center of the brain, where Leonardo located the *senso comune*. The nerves do not in reality converge in this way, so Leonardo's arrangement followed what he thought should be, rather than what he had actually observed.

Locus of the Soul

To Leonardo, the judging of information by the soul also took place in the *senso comune*. "The soul seems to reside in the judgment, and the judgment would seem to be seated in that part where all the senses meet; and this is called the *senso comune,*" he wrote circa 1489. "All our knowledge has its origin in our [sense] perceptions," he concluded. Visual objects, smells and sounds converge on the *senso comune,* while "perforated cords" convey sensory information from the skin.

Leonardo invoked a military metaphor to explain how motor output is also controlled by the *senso comune* and the soul. As he put it, "the nerves with their muscles obey the tendons as soldiers obey the officers, and the tendons obey the *senso comune* as the officers obey the general. Thus, the joint of the bones obeys the nerve, and the nerve the muscle, and the muscle the tendon, and the tendon the *senso comune*. And the *senso comune* is the seat of the soul, and memory is its ammunition, and the *imprensiva* is its standard of reference because the sense waits on the soul and not the soul on the sense. And where the sense that ministers to the soul is not at the service of the soul, all the functions of that sense are also wanting in that man's life, as is seen in those born mute and blind."

Leonardo's interest in the soul often turned to such questions of disease. He wrote: "How nerves sometimes operate by themselves without any command from other functioning parts of the soul. This is clearly apparent, for you will see paralytics and those who are shivering and benumbed by cold move their trembling parts such as head or hands without the permission of the soul; which soul with

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In later work, Leonardo progressed to where he drew what he saw, not what he had been taught to see, yielding greater accuracy.

SUPERSTOCK

all its forces cannot prevent these parts from trembling. This same thing happens with epilepsy and with severed parts such as the tails of lizards."

Because Leonardo based his theories of the mind on physical laws, he sometimes was led in unexpected directions. For instance, he argued at length that ghosts cannot exist: "There can be no voice where there is no motion or percussion of the air; there can be no percussion of the air where there is no instrument; there can be no instrument without a body; and this being so, a spirit can have neither voice nor form nor strength."

After 1493, Leonardo set his anatomical studies aside for about 15 years. He remained in Milan through the 1490s, working as an entertainer in the court of Ludovico Sforza, engaging in artistic projects such as the *Last Supper,* performing civil and military engineering, and writing his treatise on the

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elements of machines. In 1505 he continued his earlier studies of the flight of birds and the possibilities of human-powered airplanes and gliders. His focus on mathematics sharpened as he tried to apply the science of perspective to his painting. His efforts were shaped by an obsessive desire to understand what he called the four powers of nature: movement, weight, force and percussion.

Leonardo's belief in the body as a mechanical instrument subject to these four powers led him to impressive innovations when he returned to the topic of anatomy. Consider his studies of the heart. He was the first to realize that the organ has four chambers, not two, and he discovered the atria (what he called the two "upper ventricles"). He correctly surmised that the atria contract to propel blood. During an autopsy, he even identified an atrial septal defect, a hole in the septum separating the two atria. He made a three-dimensional glass cast of the aorta to study its function and performed detailed investigations (including glass models) of the tricuspid, pulmonary, mitral and aortic valves. He discovered the moderator band, a muscle spanning the right ventricle.

And so when Leonardo again took up his explorations of the structure and function of the brain, around 1508 to 1509, his approach was built on a sounder background than his initial studies had been. He invented a brilliant technique: after drilling a hole in the base of the brain of a dead ox, he used a syringe to inject hot wax into the ventricles. When the wax set, he cut away the brain tissue and thus made a reasonably accurate cast of the ventricles. This is the first known use of a solidifying medium to measure the size and shape of any internal body structure, and it provides an example of how Leonardo used his training as an artist to develop a new scientific approach.

I recently repeated the experiment by melting on a hot plate wax from a local beekeeper. I injected the hot wax into the openings of the third and fourth ventricles in a cow brain I obtained from a slaughterhouse. Within seconds the wax cooled and hardened, making a perfect cast.

Leonardo showed extraordinary creativity in deciding on this approach (no doubt inspired by his experience as a sculptor), as well as technical skills. He proceeded to make an impressive drawing of a human head, this time depicting the ventricles in more realistic shapes based on what he had observed in the ox. Equally astute was his positioning of the cranial nerves. We can identify seven pairs, including the olfactory nerves, which had never before been described as cranial nerves, and the optic nerves. He was the first to diagram in a naturalistic way how the nerves cross over at the optic chiasma. All these cranial nerves no longer entered the ventricles, as they had in the traditional illustrations, but instead traversed the surrounding brain tissue. Leonardo had progressed as an anatomist to the point that he drew what he saw, even when it contradicted the enormous weight of authority.

Leonardo performed his experiments on the brain in a broader context of his studies on the nature of sensory stimuli and the function of the eye. He maintained a largely traditional theory of how the eye detects images. Light, he believed, is a "power" that carries visual rays from an object to the eye in the form of "pyramids" that meet the eye at the top of the pyramid. Waves of "percussion" pass through the pupil and lens down the optic nerve to the *imprensiva* and then to the *senso comune,* where they enter consciousness. Having read the literature regarding optics and then performed his own experiments, Leonardo struggled to the conclusion that we see objects because the eye receives light. This view was in opposition to those espoused by Plato, Euclid, Galen and others, who held that visual power emanated from the eye, although it was supported by some, including the great Arab philosopher and physicist Alhazen.

DESPITE CHALLENGES, LEONARDO MADE ENORMOUS STRIDES IN ONE LIFETIME.

Despite such challenges, Leonardo made enormous strides in one lifetime. If he could travel forward in time to visit our society, he would surely marvel at our further progress in understanding the brain's physical functions through the use of observation and experimentation. At the same time, he might be surprised to learn how many of the questions he posed still remain incompletely addressed by modern neuroscience: How is it that we read or remember? Why do some people have intellectual disabilities or epilepsy? Why do we dream or even sleep? What is the soul? Thanks in part to the foundations laid by Leonardo and others, perhaps we will have answers within the next five centuries. M

MORE TO EXPLORE

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UNVEILING THE REAL EVIL GENIUS

CREATIVE PEOPLE ARE BETTER AT RATIONALIZING SMALL ETHICAL LAPSES THAT CAN SPIRAL OUT OF CONTROL

By Ingrid Wickelgren

Behavioral economist Dan Ariely of Duke University has probed the origins of dishonesty. Among his insights: creativity can contribute.

GABRIELA HASBUN *Redux Pictures*

In 1940 Action Comics introduced a brilliant supervillain named Lex Luthor who tries to kill Superman to advance his plot to rule the world. More recently, news articles portrayed Bernard Madoff as an "evil genius" because of his Ponzi scheme that siphoned some $20 billion from investors.

We think of an evil genius as someone who devises a clever plan for wrongdoing on a large scale. According to behavioral economist Dan Ariely of Duke University, however, the genius of the perpetrators often manifests itself not in elaborate planning of misdeeds but in almost the exact opposite: an unplanned escalation of a minor wrong they imaginatively have justified to themselves. I spoke with Ariely, author of *The (Honest) Truth about Dishonesty* (Harper, 2012), about the true origins of evil genius. Interview excerpts follow.

Creativity, or genius, is usually thought to be a positive attribute. What made you think it might have a dark side?

There are two models of dishonest behavior. The economic model is one in which people do a cost-benefit analysis. You go by a store and ask yourself, "How much money do they have in the store, and what are the chances I'd be caught?" You then decide whether to rob the store or not. We found very little evidence that this is how people think.

What we do find is that lots of us are able to cheat a little bit and still think of ourselves as honest people. This suggests that dishonesty is all about rationalization. It's all about the small acts we can take and then think to ourselves, "No, this is not real cheating." Think about people who do accounting fraud. When they start, they say to themselves, "The rules of accounting are so unclear, is it really so bad?" Or they say, "I'll fix it in the next quarter." Or think about when Clinton said, "I did not have sexual relations with that woman, Miss Lewinsky." At the

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time, he likely redefined sexual relations, and in his mind he really didn't cheat.

So I wondered: What kind of people would be able to rationalize better than others? Creative people will be able to tell themselves better stories. Intelligence doesn't change anything, we found. It's not the smartness part. The creativity part lets you find all kinds of ways to convince yourself that what you're doing is actually okay.

Are all creative people more dishonest, or are other personality characteristics required?

It's very easy to think that dishonesty is only a function of the individual, but the reality is that the environment plays a big role. You cheat when the rules are flexible or not very clear and when you have a conflict of interest or a reason to have a biased perception of reality. Let's say you and I think of ourselves as honest people. But imagine we were on Wall Street in 2007, and we could get a $10-million bonus if only we could see mortgage-backed securities as a good product. With $10 million on the line, you could probably convince yourself these securities are quite good—or at least better than they are. But if the environment doesn't allow for dishonesty, creativity won't be such a big deal. If you put a creative person in a military academy, where he has no flexibility in his decisions, he will be perfectly honest.

When we think about evil genius, we imagine clever plots to take over the world. But most creative dishonesty isn't like that, is it?

It's important to distinguish between how acts of dishonesty start and how they end. I've been interviewing cheaters, people who are involved in all kinds of white-collar crime. I've tried to talk to Madoff—he [rarely talks] to anybody—but I've talked to people who know him. He took lots of money from people and yet didn't seem to think about the endgame. If you or I were going to steal $20 billion, wouldn't we find a nice island somewhere with no extradition rules and figure out how to get there when the time comes? I would speculate that when he started, he did not have a long-term plan. I suspect that in the first quarter, he said, "I'll just do this for one quarter, and then next quarter I'll make it up…." But then he fell more and more behind. I think evil geniuses start like all of us—they are maybe a little more creative, so maybe their acts are more frequent or extreme—but the vast majority get on a slippery slope, and at some point there's no way back.

What is the evidence that a creative personality can breed dishonesty?

In our first experiments, we took students and measured how creative they were using multiple methods. No matter the measure, we found that the more creative people cheated more on a math test.

Second, we tried to temporarily increase creativity in some people but not in others. There are all kinds of evidence that this works. [For tips on boosting creativity, see "Your Fertile Brain at Work," by Evangelia G. Chrysikou, on page 86; and "Let Your Creativity Soar," by Mariette DiChristina et al., on page 94.] Those in whom we increased creativity cheated a bit more. That's more causal, supporting the idea that creativity is the mechanism.

Then we went to a big advertising company and asked its employees questions that tested their moral flexibility in personal relationships, taxes, relationships with companies, and so on. If you were on a business trip, would you report a dinner you purchased after you got home on your expense report? We also asked the CEO which jobs have more or less creativity. The results showed that the more creativity in a person's job, the more moral flexibility the person reported in our survey.

How can the dark side of creativity be avoided or diminished?

Creativity is very helpful for lots of things, so we don't want to stamp it out. But if you take creative people and put them in a situation where they have a conflict of interest and where the rules are flexible, this is going to be a bad recipe. Wherever rationalization is easy, I would worry a lot about the rules, regulations and code of conduct—and then I would try to eradicate conflict of interest. In finance, you can make lots of money if you see reality in one way or another. In medicine, if a physician gets paid for prescribing a test or procedure, creativity can also play a big dangerous role. And there are cases where creativity exercises might not be beneficial. I would also worry about increasing creativity just before doing taxes or playing golf.

Is lying okay in some instances?

Not all dishonesty is bad. We all know about white lies and social politeness. Telling the truth all the time is a difficult thing to live with, which is why we often encourage some level of dishonesty. M

CREATIVITY EXERCISES MIGHT NOT ALWAYS BE BENEFICIAL. I WOULD WORRY ABOUT **BOOSTING CREATIVITY JUST BEFORE DOING TAXES OR PLAYING GOLF.**

MORE TO EXPLORE

◆ **The Dark Side of Creativity: Original Thinkers Can Be More Dishonest.** Francesca Gino and Dan Ariely in *Journal of Personality and Social Psychology,* Vol. 102, No. 3, pages 445–459; 2012.

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ANSWERS WHILE You Sleep

WHEN YOU DREAM, YOU ENTER AN ALTERNATIVE STATE OF CONSCIOUSNESS—A TIME WHEN TRUE INSPIRATION CAN STRIKE

By Deirdre Barrett
Photoillustration by Aaron Goodman

As a young mathematician in the 1950s, Don Newman taught at the Massachusetts Institute of Technology alongside rising star and Nobel-laureate-to-be John Nash. Newman had been struggling to solve a particular math problem: "I was … trying to get somewhere with it, and I couldn't and I couldn't and I couldn't," he recalled.

FAST FACTS
OPENING THE MIND

❶ The act of dreaming is simply thinking about our usual concerns in a different state of consciousness.

❷ Dreams can be especially helpful for problems that require creativity or visualization to solve.

❸ By thinking about specific dilemmas before bed, we can increase our chances that we will dream a solution.

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One night Newman dreamed that he was reflecting on the problem when Nash appeared. The sleeping Newman related the details of the conundrum to Nash and asked if he knew the solution. Nash explained how to solve it. Newman awoke realizing *he had the answer!* He spent the next several weeks turning the insight into a formal paper, which was then published in a mathematics journal.

Newman is hardly alone in making a practical breakthrough during a night of sleep. While dreaming, Friedrich August Kekulé came up with the structure of benzene, Dmitry Mendeleev conjured up his final form of the periodic table of the elements and Otto Loewi thought of the neuroscience experiment that won him a Nobel Prize in medicine.

Modern engineers Paul Horowitz and Alan Huang dreamed designs for laser-telescope controls and laser computing, respectively. Innumerable artists and filmmakers have depicted images that came to them in their sleep. Mary Shelley dreamed the two main scenes that became *Frankenstein,* and Robert Louis Stevenson did the same with *Dr. Jekyll and Mr. Hyde*. Ludwig van Beethoven, Paul McCartney and Billy Joel all awoke to discover new tunes ringing in their minds. Mahatma Gandhi's call for a nonviolent protest of British rule of India was inspired by a dream.

Yet dreams so often seem incoherent, bizarre or even trivial. We search intensely for our brother in an endless maze of corridors because we *must* give him a yellow package. But when we find him, we have forgotten the package—which we are certainly not holding any longer—and anyway he is now a neighbor, not a brother. Other dreams are ephemeral—we wake up thinking about a yellow box, but that is all we recall.

For decades scientists have puzzled over how dreams could display such diverse characteristics. Research is now suggesting that dreams are simply thought in a different biochemical state. The physiological demands of sleep alter the way the brain functions. Dreams may seem bizarre or nonsensical because the chemistry of the sleeping brain affects how we perceive our own thoughts, but we nonetheless continue focusing on all the same issues that concern us while we are awake. This unusual state of consciousness is often a blessing for problem solving—it helps us find solutions outside our normal patterns of thought. By following a few simple steps, we can even harness this power, encouraging our sleeping brain to ruminate on particular concerns.

Anatomy of a Dream

One often hears the question, "What is dreaming for?" You would never pose such a simplistic query about waking thought. It is for *everything.*

Nevertheless, theorists have long offered one-function explanations for dreaming. Sigmund Freud believed that dreams primarily express repressed wishes, namely infantile sexual and aggressive impulses. Other psychoanalysts thought dreams had more to do with narcissistic strivings or compensation for feelings of inferiority. More recently, psychologists have posited that dreams simulate threats or help to consolidate memories. All these theories characterize some dreams, but none of them can account for every type. Just as waking thought can drift between reminiscing, planning, rumination, and so on, dream cognition seems to encompass many modes of thought.

DREAMS ARE SIMPLY THOUGHT IN A DIFFERENT BIOCHEMICAL STATE. WE CONTINUE FOCUSING ON ALL THE SAME ISSUES THAT CONCERN US WHILE WE ARE AWAKE.

Most early theorists assumed that the dreams we remembered constituted *all* dreams. Several hypotheses supposed that people experienced dreams when some specific situation triggered a set of distinctive feelings—the desire for sex, say, or a bruised ego. In the 1950s, however, a series of groundbreaking studies by Eugene Aserinsky and Nathaniel Klietman, both then at the University of Chicago, revealed that people have many more dreams than they are likely to remember. The two sleep researchers discovered that human slumber

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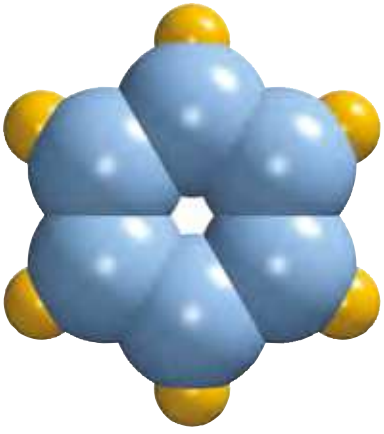

Revolutionary ideas and works of art may grow from a dream: Mary Shelley's *Frankenstein,* Dmitry Mendeleev's layout of the periodic table, Friedrich August Kekulé's discovery of benzene's structure, and architect Solange Fabião's concept for the City of the Ocean museum in Biarritz, France.

GETTY IMAGES (*Frankenstein's monster*); MARK J. WINTER *Science Source (benzene)*; CHRISTOPHER COOPER *Getty Images (periodic table)*; © PAUL RAFTERY *age fotostock (building)*

consists of approximately 90-minute cycles, each one containing a period of rapid eye movement (REM) and heightened brain activity—about as much activity as when we are awake. When the scientists awakened people near the end of each REM period, the sleepers recounted an average of almost five dreams per night. The discrepancy between the subjects' reports when awakened right after the REM period, as opposed to later, led the scientists to conclude that dreams almost always accompany this stage of sleep even if none are recalled by the morning.

Within the past two decades positron-emission tomography (PET) scans have allowed us to see which brain areas are involved in dreaming. Parts of the cortex associated with visual imagery and the perception of movement become activated even more dramatically than when we are awake, as do some deep brain areas associated with emotion. In contrast, the dorsolateral prefrontal cortex is less engaged during dreaming; this area is associated with volitional action and the evaluation of what is logical and socially appropriate. These PET results

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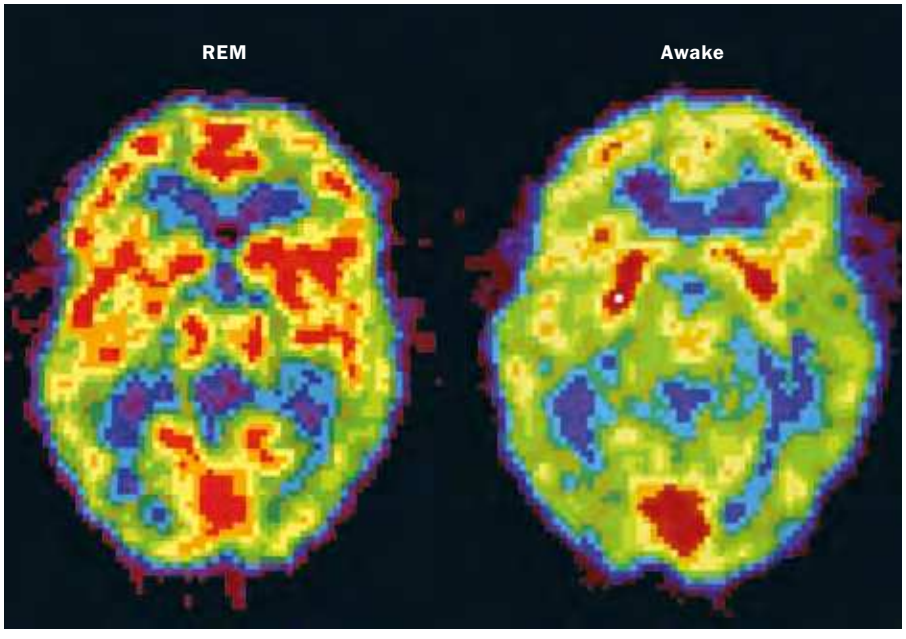
fit the characteristics of dreams well; dream reports almost always contain visual imagery and often involve movement. The prefrontal findings fit neatly with the fact that dreams have long been associated with less "censorship"—not only in the Freudian sense of uninhibited sex and aggression but also in terms of our filtering out scenarios that are illogical or abnormal. We will return to this point when discussing methods of problem solving. Sometimes tackling a puzzle the "wrong" way can lead to surprising insights.

Evolutionary psychologists were quick to point out that this PET portrait of the dreaming brain makes sense because such activity would have supported human survival—certain areas of the brain are safer to turn on and off during sleep than others. Donald Symons, an anthropologist at the University of California, Santa Barbara, argued in his 1993 paper "The Stuff That Dreams Aren't Made Of" that sleepers must monitor the environment with specific senses—to smell smoke, hear intruders, sense temperature changes and feel pain. Hallucinating vividly in those sensory modes might lead us to wake up frequently in an unnecessary panic, or, even worse, over a long period we might evolve a threshold of tolerance that would cause us to block our real warnings. Our eyes can be closed, however, because we do not need to monitor our visual environment during sleep. And our body can be paralyzed, as is normal during REM sleep, because we do not need to move—in fact, we should not move until we awaken.

Evolution, then, may help elucidate why certain brain areas are more or less active when we sleep. The pattern of activity explains why dreams have the characteristics they do—visually rich and logically loose. At first, these exciting physiological findings gave rise to a proliferation of theories that dreams were just an epiphenomenon, or side effect, of the brain patterns during slumber. Sleep researchers often referred to REM activity as "random," although no evidence suggested it was any more random than waking brain activity. Many theorists leaped to pronounce dreams "explained."

I reiterate: we would never dismiss waking thought so quickly. Knowing that our prefrontal cortex is active when we encounter a social prohibition does not explain away the subjective debate we experience when deciding how to respond. Likewise, describing a dream's content or its associated brain activity does not answer the question of its purpose. Brain researchers finally grasped this fact after a two-decade lull and in the past several years have begun studying dreams seriously again.



Sleep on It

By the 1990s a growing body of research suggested that slumber is important for consolidating new learning: even very early studies had shown that sleeping for a while after learning something new results in much better recall than after spending the same amount of time awake. More recent findings hint at a special role

Dreams occur in rapid eye movement (REM) sleep, during which the brain is just as active as when we are awake. Here positron-emission tomography scans show the brain during REM sleep (*left*) and while awake (*right*). Activity is indicated by the color spectrum, with red indicating the most active areas and blue the least.

YINYANG *Getty Images (top)*; HANK MORGAN *Science Source (bottom)*

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for REM sleep in memory consolidation. Studies of rats learning to navigate mazes have found that during REM sleep, brain activity mimics that of the awake rodent training in the maze, which suggests that circuits may be reinforced during REM sleep. In humans, too, research supports the role of REM sleep in memory. The more REM sleep subjects get after learning, the better they recall emotionally charged material.

In 2009 psychologists at the University of California, San Diego, examined whether REM facilitated more than just memory when learning. They gave their subjects a test that required creative problem solving and then dropped hints about the answers. The subjects then spent some time either awake, in non-REM sleep only or in REM sleep before taking the test again. The REM sleep group showed the most improvement on their creative solutions to the previously presented problems.

The same year in Robert Stickgold's lab at Harvard University, a team led by then postdoctoral researcher Ina Djonlagic had subjects learn a complicated system of weather prediction. The students were shown a combination of images, each representing a probability of sun or rain. The students did not know the meaning of the images, but they attempted to figure them out through trial and error by predicting an overall chance of sun or rain and getting feedback on their answers. The researchers found that subjects who nodded off before doing the task again were more likely to discover the general rule behind the images' meaning through an "aha!" type of insight than those who stayed awake. In addition, their heightened performance, as well as their ability to explicitly articulate that they had grasped the general rule, was correlated with the amount of REM sleep they had gotten.

Further research confirms that REM sleep aids in problem solving. In a series of studies in the same Harvard lab, Erin J. Wamsley, also then a postdoctoral researcher, asked subjects to navigate a virtual maze. After some practice, they got either a waking break, REM sleep or a non-REM sleep period. As Wamsley reported at the 2011 SLEEP conference, only REM sleep sharpens participants' performance. In addition, when she woke or interrupted them to ask what they are thinking or dreaming, the theme was often the maze—but only when this thinking occurs in REM sleep did subjects fare better the next time they tackle the real maze.

Because REM sleep is the stage during which dreams occur, these sleep studies imply that dreaming might have something to do with creative problem solving. Mounting experimental evidence, as well as countless anecdotes of solutions that popped up during dreams, supports this idea.

The first study on dreams and objective problem solving was conducted more than a century ago. In 1892 Charles M. Child of Wesleyan University asked 186 college students whether they had ever addressed a problem in a dream. One third said they had. The students reported playing a chess game, solving an algebra problem, detecting a bookkeeping error and translating a passage from Virgil while slumbering.

BRAIN AREAS THAT RESTRICT OUR THINKING TO THE LOGICAL AND FAMILIAR ARE MUCH LESS ACTIVE DURING REM SLEEP. SUCH DISINHIBITION IS A CRUCIAL PART OF CREATIVE THOUGHT.

The next major breakthrough came when researchers decided to try seeding people's dreams with a specific problem. In 1972 sleep researcher William Dement of Stanford University asked 500 of his students to spend 15 minutes a night trying to solve brainteasers, making sure that they fell asleep with an unsolved problem on their mind. Students reported having 87 dreams, seven of which solved a brainteaser.

Such puzzles are a useful tool for testing creative problem solving because people are likely to get stuck before having an "aha!" moment of insight. Yet these brainteasers may be beyond the ability of some subjects, and they are also not of great personal import. In Dement's study, which lasted three nights, all the correct answers came during the first night. He surmised that students lost motivation quickly on problems of little relevance to their lives. Therefore, in my own research in 1996, I took a different approach. I asked students to select their own objective problem. They recorded their dreams for a week and noted the ones they thought addressed the issue or contained a satisfactory solution. Two research assistants also judged whether the dreams focused on or solved the problems.

Most of my subjects chose problems that appeared simpler than Dement's brainteasers. Half of

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HOW TO TRAIN YOUR DREAMS

Intentionally trying to dream about a particular problem, called dream incubation, increases the chance that you will come up with a solution. The term "incubation" was borrowed from ancient Greek practices at the temples of Asclepius. There the ill tried to have dreams that would tell them how to cure their malady. In Western psychology, here is how we harness our dreams:

1. Write down your problem as a brief phrase or sentence and place this note next to your bed. Also keep a pen and paper—and perhaps a flashlight—alongside it.
2. Review the problem for a few minutes before going to bed.
3. Once in bed, visualize the problem as a concrete image, if possible.
4. Tell yourself you want to dream about the problem as you drift off to sleep.
5. On awakening, lie quietly before getting out of bed. Note whether you recall any trace of a dream and try to invite more of the dream to return. Write it down.

If you want a more elaborate process, add these steps to your incubation routine:

6. At bedtime, picture yourself dreaming about the problem, awakening and writing on your bedside notepad.
7. Arrange objects connected to the problem on your night table or on the wall across from your bed.

—*D.B.*

them had dreams they felt touched on their concern, and one third dreamed a solution to it. Judges rated only slightly fewer dreams as tackling or solving problems. Although a number of the problems had to do with homework or mundane tasks such as rearranging furniture, some of the most interesting solutions came up in dreams about major life decisions. For instance, this dilemma was rated as solved by both the dreamer and the judges:

> ***Problem:*** I have applied to two programs in clinical psychology and two in industrial psychology because I can't decide which field I want to go into.
> ***Dream:*** There's a map of the U.S., and I'm in a plane flying over this map. The pilot says we're having engine trouble and need to land. We look for a safe place on the map, indicated by a light. I ask about Massachusetts, which we're right over, but he says that all of Massachusetts is very dangerous. The lights seemed to be farther west.
> ***Solution:*** I woke up and realized that my two clinical schools are both in Massachusetts, where I have spent my entire life and where my parents live. Both industrial programs are far away, in Texas and California. This is because originally I was looking to stay close to home, and there were no good industrial programs nearby. I realized that there is a lot wrong with staying at home, and funny as it sounds, getting away is probably more important than which kind of program I go into.

A Portal to Creativity

The all-time most famous dream example—Kekulé realizing that the structure of benzene was a closed ring after dreaming of a snake made of atoms taking its tail in its mouth—illustrates the two distinctive features of problem solving in dreams. Recall that the brain areas that usually restrict our thinking to the logical and familiar are much less active during REM sleep. Many studies of creativity suggest that such disinhibition is a crucial component of creative thought. [For more on how cognitive disinhibition allows new ideas to surface, see "The Unleashed Mind," by Shelley Carson, on page 28.] Similarly,

TARA MOORE *Aurora Photos*

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the high activity in the visual areas of the sleeping brain allows it to visualize solutions more readily than in waking thought. Kekulé had been stumped because all known molecules were straight lines with side chains, and he had assumed, wrongly, that benzene would follow suit.

My research confirms that dreamed solutions tend to have unusual visual characteristics. Through the late 1990s I scoured the existing literature on dreams, combed professional biographies and history books for examples of problem-solving dreams, and queried working professionals as to whether they had ever had dreams that were useful in their jobs. Certain patterns emerged from this research. Well over half of the visual artists said they had used dreams in their work. About half of fiction writers had. The numbers dropped off rapidly as the professions became more abstract. Within the sciences, inventors, engineers and others who benefit from visualizing problems in three dimensions were likelier to report helpful dreams. Some dreamers even had multiple examples of having awakened with a solution and had developed an explicit bedtime incubation routine.

In a study for which I reported preliminary results in June 2011 at the International Association for the Study of Dreams Conference, I investigated how dream-based problem solving might benefit working men and women more broadly. Professionals aged 21 to 69 attempted to solve real work-related problems in their sleep. These subjects seemed to dream about their problems with the same frequency as the college students I had observed in 1996; however, they reported less than half the number of solutions as compared with the students. The work-related problems may simply be more difficult than the college students' dilemmas, and because this group is older, the subjects may not recall as many dreams. A significant number of them, however, did report having a useful dream after only one week of incubation practice [*see box on opposite page*].

Your Dreams

Shortly after my book *The Committee of Sleep* was published in 2001, I heard Newman recount his story on a PBS show about John Nash and the film *A Beautiful Mind*. A year later I was unexpectedly seated next to Nash at a dinner party. I asked him about the incident, which he remembered well. "Don actually included a footnote thanking me in the paper," Nash chuckled, "and he kept acting grateful, like I'd actually helped him when it was *his* dream." I came across that remark often in my survey. Solutions frequently came from a dream character—one computer programmer got repeated nocturnal lessons from Albert Einstein—and people had trouble taking full credit for what their dreaming mind had done. This tendency fits brain findings for REM sleep in which the dorsolateral prefrontal cortex, associated with perceptions of volition, is less active than parts of the brain associated with perceptions of visual images, movement and emotions.

But we need not wait passively for inspiration to strike. We spend almost a third of our lives asleep—and almost a third of *that* time dreaming. My research suggests that in a short amount of time, people can learn to focus their dreams on minor problems and often solve them. As for the bigger concerns, surveys find that all kinds of mysteries can be revealed in dreams—two Nobel Prizes resulted from dreams, after all. But even if you choose to leave your sleeping brain alone, pay attention: after nodding off, your brain in its altered state of consciousness is very likely already hard at work. M

SOLUTIONS FREQUENTLY CAME FROM A DREAM CHARACTER, AND PEOPLE HAD TROUBLE TAKING FULL CREDIT FOR WHAT THEIR DREAMING MIND HAD DONE.

MORE TO EXPLORE

- **REM, Not Incubation, Improves Creativity by Priming Associative Networks.** D. J. Cai, S. A. Mednick, E. M. Harrison, J. C. Kanady and S. C. Mednick in *Proceedings of the National Academy of Sciences USA,* Vol. 106, No. 25, pages 10,130–10,134; June 23, 2009.
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- International Association for the Study of Dreams Web site: **www.asdreams.org**

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UNLOCKING THE **LUCID** DREAM

BECOMING AWARE OF YOUR SLEEPING SELF COULD RELIEVE ANXIETY OR TAP THE CREATIVE UNCONSCIOUS

By Ursula Voss

I moved my eyes, and I realized that I was asleep in bed. When I saw the beautiful landscape start to blur, I thought to myself, "This is my dream; I want it to stay!" And the scene reappeared. Then I thought to myself how nice it would be to gallop through this landscape. I got myself a horse … I could feel myself riding the horse and lying in bed at the same time.

FAST FACTS

ASLEEP YET AWARE

❶ Approximately eight out of 10 people have had a lucid dream, in which they were conscious of their dreaming, at least once.

❷ Parts of the brain tend to work together more intensely during lucid dreaming than in other dream phases.

❸ Lucid dreaming is useful for treating chronic nightmares and perhaps even anxiety.

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So recounted a test subject in the sleep laboratory at the University of Bonn in Germany. This particular sleeper was having a lucid dream, in which the dreamer recognizes that he or she is dreaming and can sometimes influence the course of the dream. By measuring the brain waves of lucid dreamers, my colleagues have gained a better understanding of the neural processes underlying this state of consciousness that exists between sleep and waking. In addition to providing clues about the nature of consciousness, research on lucid dreams is also beginning to suggest new ways to treat anxiety and learn complex movements while asleep.

Most people report having a lucid dream at least once in their life, and a small fraction of us have them as often as once or twice a week. Some individuals even develop routines to increase their chances of having a lucid dream [*see box on opposite page*]. But researchers who wanted to study lucid dreams were long confounded by the need to rely on subjects' self-reports. The process of recall is notoriously prone to distortion; for example, some people may confuse lucid dreams with the transient hallucinations that occur while falling asleep or waking up.

In the mid-1970s some pioneers in the sleep research field figured out a way to prevent such misinterpretation. The researchers instructed subjects to move their eyes a certain way as soon as the sleepers recognized that they were dreaming, for example, by rolling their eyes twice from left to right. These signals can be easily distinguished from the rapid eye movement (REM) that occurs randomly during dreams. We still use this method today.

After a sleeper has signaled with eye movements that a lucid dream has started, researchers can investigate the corresponding brain activity using electroencephalography (EEG). In an EEG recording, electrodes attached to the skin of the head pick up the oscillating electrical signals that indicate that thousands or millions of neurons are firing in synchrony. Recent studies indicate that the brain's activity during lucid dreaming resembles that of waking consciousness.

In 2009 my team and I decided to take a closer look at the brain activity of lucid dreamers. In the sleep lab, we found what we believe to be an electrical signature of lucid dreaming—increased activity in the 40-hertz range (the "gamma band"), primarily in the frontal lobe, located behind the forehead. We tend to generate these high-frequency waves when we concentrate on a particular object. In addition to the frontal lobe, other regions of the cerebral cortex—the rippled mantle on the surface of the brain—play a major role in lucid dreaming. The frontal lobe seems to work in lucid dreams much as it does in the waking state.

Another striking feature in our study involved coherence—a rough measure of how coordinated the activity is in various areas of the brain. Coherence is generally slightly decreased in REM sleep but not during lucid dreams. Think of the brain's activity during REM sleep

CHRONIC NIGHTMARE SUFFERERS OFTEN FIND THEIR ONLY SOURCE OF RELIEF IS LEARNING HOW TO TAKE CONTROL OF THEIR DREAMS. BECOMING AWARE MAY CREATE EMOTIONAL DISTANCE.

THE AUTHOR

URSULA VOSS lectures at Goethe University Frankfurt in Germany and heads the clinical neuropsychology department at Vitos Hochtaunus Hospital.

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AM I DREAMING?

Lucid dreams cannot be willfully induced, but you can increase the likelihood that you will have one. People who practice these techniques regularly are able to have one or two lucid dreams a week.

1. Throughout each day, ask yourself repeatedly if you are awake. When this habit becomes ingrained, you may find yourself asking the question in a dream—at which point your chances of realizing you are dreaming skyrocket.
2. Make a point to look in a mirror or reread a bit of text every so often as a "reality check." In dreams, our appearance is often altered and the written word is notoriously hard to pin down. You may carry the habit of checking for these dream signs into sleep, where they could alert you to the fact that you are dreaming.
3. Keep a dream journal by the bed and jot down the dreams you remember immediately on waking. Studies show that this practice makes you more aware of your dreams in general, and people who are more aware of their dreams are more likely to have a lucid dream.
4. Before falling asleep, focus intently on the fantasy you hope to experience in as much detail as possible. Research shows that "incubating" an idea just before bed dramatically increases the likelihood that you will dream about it. And if you suddenly notice that you are dancing with the movie star you hoped to meet, you might just realize you are having a dream and be able to take control of what happens next.

Adapted from the Lucidity Institute's Web site: www.lucidity.com

as equivalent to a party with all the guests talking simultaneously. In lucid dreams, however, the party guests converse with one another, and the background noise decreases.

Beyond Fantasies

Until recently, most experts thought of lucid dreaming as a curiosity—a fun way to act out wishful thinking about flying or meeting celebrities—but research has uncovered practical uses. Chronic nightmare sufferers often find their only source of relief is learning how to take control of their dreams. A study in October 2006 in *Psychotherapy and Psychosomatics* found that those who learned how to increase their frequency of lucid dreams reported fewer awful dreams, although the exact mechanism underlying the relief is unclear. Perhaps becoming aware during a bad dream allows sufferers to distance themselves emotionally from the content.

In theory, lucid dreams could help alleviate generalized anxiety or the reaction to specific stimuli (for instance, spiders) by allowing people to confront worries and frights in the safe environment afforded by knowing "it's just a dream." Our work with patients suffering from post-traumatic stress disorder suggests that learning how to control dreams reduces the fear of dreaming, boosts self-confidence and makes patients more optimistic about their ability to eventually cope with their trauma.

Beyond therapeutic applications, lucid dreaming may also improve athletic performance. According to sports psychologist Daniel Erlacher of the University of Bern in Switzerland, athletes can internalize complex motor sequences, such as those needed in the high jump, more quickly after targeted lucid-dreaming training.

Some researchers have asked whether lucid dreams could be useful in focusing the dreamer's mind for problem-solving purposes. A small study in 2010 at Liverpool John Moores University in England suggested that lucid dreams are good for creative endeavors such as inventing metaphors but not for more rational exercises such as solving brainteasers. The lucid dreamers in the study were instructed to summon a "guru" figure, a wise character to serve as a kind of guide. Indeed, some of the subjects found their dream characters to be surprisingly helpful.

We still have much to learn about lucid dreaming. For example, we do not know under what circumstances these dreams appear most frequently or how to induce them more reliably. What we have learned is that lucid dreaming is frequent in children until around age 16, particularly in children with higher cognitive abilities. This leads us to believe that lucid dreaming occurs naturally in the course of frontal lobe integration and brain maturation. Of course, it also raises many new questions, such as whether lucid dreaming may prove useful in enhancing cognitive functioning. Lucid dreaming's potential for therapy, problem solving or pure entertainment could be limitless. M

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LIVING IN AN IMAGINARY WORLD

DAYDREAMING CAN HELP SOLVE PROBLEMS, TRIGGER CREATIVITY, AND INSPIRE GREAT WORKS OF ART AND SCIENCE. WHEN IT BECOMES COMPULSIVE, HOWEVER, THE CONSEQUENCES CAN BE DIRE

By Josie Glausiusz
Photoillustration by Aaron Goodman

When Rachel Stein (not her real name) was a small child, she would pace around in a circle shaking a string for hours at a time, mentally spinning intricate alternative plots for her favorite television shows. Usually she was the star—the imaginary seventh child in *The Brady Bunch,* for example. "Around the age of eight or nine, my older brother said, 'You're doing this on the front lawn, and the neighbors are looking at you. You just can't do it anymore,' " Stein recalls.

So she retreated to her bedroom, reveling in her elaborate reveries alone. As she grew older, the television shows changed—first *General Hospital,* then *The West Wing*—but her intense need to immerse herself in her imaginary world did not.

"There were periods in my life when daydreaming just took over everything," she recalls. "I was not in control." She would retreat into fantasy "any waking moment when I could get away with it. It was the first thing I wanted to do when I woke up in the morning. When I woke up in the night to go to the bathroom, it would be bad if I got caught up in a story because then I couldn't go back to sleep." By the time she was 17,

FAST FACTS
INNER WORLD

❶ Daydreams are an inner world where we can rehearse the future and imagine new adventures without risk. Allowing the mind to roam freely can aid creativity—but only if we pay attention to the content of our daydreams.

❷ Neuroscientists have identified the "default network"—a web of brain regions that become active when we mentally drift away from the task at hand into our own reveries.

❸ When daydreaming turns addictive and compulsive, it can overwhelm normal functioning, impeding relationships and work.

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Stein was exhausted. "I loved the daydreams, but I just felt it was consuming my real life. I went to parties with friends, but I just couldn't wait to get home. There was nothing else that I wanted to do as much as daydreaming."

Convinced that she was crazy, she consulted six different therapists, none of whom could find anything wrong with her. The seventh prescribed Prozac, which had no effect. Eventually Stein began taking another antidepressant, Luvox, which, like Prozac, is also a selective serotonin reuptake inhibitor but is usually prescribed for obsessive-compulsive disorder. Gradually she brought her daydreaming under control. By age 39, she was a successful lawyer, still nervously guarding her secret world.

The scientific study of people such as Stein is helping researchers better understand the role of daydreaming in normal consciousness—and what can happen when this process becomes unhealthy. For most of us, daydreaming is a virtual world where we can rehearse the future, explore fearful scenarios or imagine new adventures without risk. It can help us devise creative solutions to problems or prompt us, while immersed in one task, with reminders of other important goals.

For others, however, the draw of an alternative reality borders on addiction, choking off other aspects of everyday life, including relationships and work. Starring as idealized versions of themselves—as royalty, raconteurs and saviors in a complex, ever changing cast of characters—addictive daydreamers may feel enhanced confidence and validation. Their fantasies may be followed by feelings of dread and shame, and they may compare the habit to a drug or describe an experience akin to drowning in honey.

The recent discovery of a network in the brain dedicated to autobiographical mental imagery is helping researchers understand the multiple purposes that daydreaming serves in our lives. They have dubbed this web of neurons "the default network" because when we are not absorbed in more focused tasks, the network fires up. The default network appears to be essential to generating our sense of self, suggesting that daydreaming plays a crucial role in who we are and how we integrate the outside world into our inner lives. Cognitive psychologists are now also examining how brain disease may impair our ability to meander mentally and what the consequences are when we just spend too much time, well, out to lunch.

MOST PEOPLE SPEND BETWEEN 30 AND 47 PERCENT OF THEIR WAKING HOURS SPACING OUT, DRIFTING OFF, LOST IN THOUGHT, WOOLGATHERING—OR, AS ONE SCIENTIST PUT IT, "WATCHING YOUR OWN MENTAL VIDEOS."

Videos in the Mind's Eye

Most people spend between 30 and 47 percent of their waking hours spacing out, drifting off, lost in thought, woolgathering, in a brown study or building castles in the air. Yale University emeritus psychology professor Jerome L. Singer defines daydreaming as shifting attention "away from some primary physical or mental task toward an unfolding sequence of private responses" or, more simply, "watching your own mental videos." Singer, who published a lyrical account of his decades of research on daydreams in his 1975 book, *The Inner World of Daydreaming* (Harper & Row), divides daydreaming styles into two main categories: "positive-constructive," which includes upbeat and imaginative thoughts, and "dysphoric," which encompasses visions of failure or punishment. Most people experience both kinds to some degree.

Other scientists distinguish between mundane musings and extravagant fantasies. Michael Kane, a cognitive psychologist at the University of North Carolina at Greensboro, considers "mind wandering" to be "any thoughts that are unrelated to one's task at hand." In his view, mind wandering is a broad category that may include everything from pondering ingredients for a dinner recipe to saving the planet from alien invasion. Most of the time when people fall into mind wandering, they are thinking about everyday concerns, such as recent encounters and items on their to-do list. More exotic daydreams in the style of James Thurber's grandiose fictional fantasist Walter Mitty—such as Mitty's dream of piloting an eight-engine hydroplane through a hurricane—are rare.

Humdrum concerns figured prominently in one study that rigorously measured how much time we spend mind wandering in daily life. In a 2009 study Kane and his colleague Jennifer McVay asked 72 U.N.C. students to carry PalmPilots that beeped at random intervals eight times a day for a week. The subjects then recorded their thoughts at that moment on a questionnaire. About 30 percent of the beeps coincided with thoughts unrelated to the task at hand. Mind wandering increased with stress, boredom or sleepiness or in chaotic environments and decreased with enjoyable tasks. That may be because enjoyable activities tend to grab our attention.

Intense focus on our problems may not always lead to immediate solutions. Instead allowing the mind to float freely can enable us to access unconscious ideas hovering underneath the surface—a process that can lead to creative insight, according to psychologist Jonathan W. Schooler of the University of California, Santa Barbara.

We may not even be aware that we are daydreaming. We have all had the experience of "reading" a book yet absorbing nothing—moving our eyes over the words on a page as our attention wanders and the text turns into gibberish. "People oftentimes don't realize that

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People's minds typically wander to everyday concerns, such as conversations with co-workers or errands to be run. More elaborate fantasies—such as Walter MItty's of piloting a plane—are far less common.

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they're daydreaming while they're daydreaming; they lack what I call 'meta-awareness,' consciousness of what is currently going on in their mind," Schooler says. Aimless rambling across the moors of our imaginings may allow us to stumble on ideas and associations that we may never find if we strive to seek them.

A Key to Creativity

Artists and scientists are well acquainted with such playful fantasizing. Orhan Pamuk, the Turkish novelist who won the Nobel Prize in Literature in 2006, imagined "another world," to which he retreated as a child, where he was "someone else, somewhere else … in my grandmother's sitting room, I'd pretend to be inside a submarine." Albert Einstein pictured himself running along a light wave—a reverie that led to his theory of special relativity. Filmmaker Tim Burton daydreamed his way to Hollywood success, spending his childhood holed up in his bedroom, creating posters for an imaginary horror film series.

Why should daydreaming aid creativity? It may be in part because the waking brain is never really at rest. As psychologist Eric Klinger of the University of Minnesota explains, floating in unfocused mental space serves an evolutionary purpose: when we are engaged with one task, mind wandering can trigger reminders of other, concurrent goals so that we do not lose sight of them. Some researchers believe that increasing the amount of imaginative daydreaming we do or replaying variants of the millions of events we store in our brain can be beneficial. A painful procedure in a doctor's office, for example, can be made less distressing by visualizations of soothing scenes from childhood.

Yet to enhance creativity, it is important to pay attention to daydreams. Schooler calls this "tuning out" or deliberate "off-task thinking." In one of his studies, he and his colleague Jonathan Smallwood asked 122 undergraduates at the University of British Columbia to read a children's story and press a button each time they caught themselves tuning out. The researchers also periodically interrupted the students as they were reading and asked them if they were "zoning out" or drifting off without being aware of it. "What we find is that the people who regularly catch themselves—who notice when they're doing it—seem to be the most creative," Schooler says. Such sub-

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If you are faced with a difficult decision, try not to think about the problem for a while. Instead do something else while letting your mind ramble. You may get a flash of insight from your subconscious that will lead you in the right direction.

jects score higher on a standard test of creativity, in which they are asked to describe all the uses of a common object, such as a brick; high scorers compile a longer and more creative list. "You need to have the mind-wandering process," he explains, "but you also need to have meta-awareness to say, 'That's a creative idea that popped into my mind.' "

The mind's freedom to wander during a period of deliberate tuning out could also explain the flash of insight that may pop into a person's head when he or she takes a break from an unsolved problem. Ut Na Sio, now at Carnegie Mellon University, and Thomas Ormerod, now at the University of Sussex in England, conducted a meta-analysis of studies of these brief reveries. They found that people engaged in a mildly demanding task, such as reading during a break from, say, a visual assignment such as the hat-rack problem—in which participants have to construct a sturdy hat rack using two boards and a clamp—did better on that problem than those who did nothing at all. They also scored higher than those engaged in a highly demanding task—such as mentally rotating shapes—during the interval. Allowing our mind to ramble during a moderately challenging task, it seems, enables us to access ideas not easily available to our conscious mind or to combine these insights in original ways. Our ability to do so is now known to depend on the normal functioning of a dedicated daydreaming network deep in our brain.

The Mental Matrix of Fantasy

Like Facebook for the brain, the default network is a bustling web of memories and streaming movies, starring ourselves. "When we daydream, we're at the center of the universe," says neurologist Marcus Raichle of Washington University in St. Louis, who first described the network in 2001. It consists of three main regions: the medial prefrontal cortex, the posterior cingulate cortex and the parietal cortex. The medial prefrontal cortex helps us imagine ourselves and the thoughts and feelings of others; the posterior cingulate cortex draws personal memories from the brain; and the parietal cortex has major connections with the hippocampus, which stores episodic memories—what we ate for breakfast, say—but not impersonal facts, such as the capital of Kyrgyzstan. "The default mode network is critical to the establishment of a sense of self," Raichle says.

It was not until 2007, however, that cognitive psychologist Malia Fox Mason, now at Columbia University, discovered that the default network—which lights up when people switch from an attention-demanding activity to drifting reveries with no specific goal—becomes more active when people engage in a monotonous verbal task, when they are more likely to mind wander. In an experiment, participants were shown a string of four letters

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such as R H V X for one second, which was then replaced by an arrow pointing either left or right, to indicate whether the sequence should be read forward or backward. When one of the characters in the string appeared, subjects were asked to indicate its position (first, second, third or last, depending on the direction of the arrow). The more the participants practiced on each of the four original letter strings, the better they performed. They were then given a novel task, consisting of letter sequences they had not seen before. Activity in the default network went down during the novel version of the test. Subjects who daydreamed more in everyday life—as determined by a questionnaire—also showed greater activity in the default network during the monotonous original task.

Mason did not directly measure mind wandering during the scans, however, so she could not determine exactly when subjects were "on task" and when they were daydreaming. In 2009 Smallwood, Schooler and Kalina Christoff of the University of British Columbia published the first study to directly link mind wandering with increased activity in the default network. The researchers scanned the brains of 15 U.B.C. students while they performed a simple task in which they were shown random numbers from zero to nine. Each was asked to push a button when he or she saw any number except three. In the seconds before making an error—a key sign that an individual's attention had drifted—default network activity shot up. Periodically the investigators also interrupted the subjects and asked them if they had zoned out. Again, activity in the default network was higher in the seconds before the moment they were caught in the act. Notably, activity was strongest when people were unaware that they had lost their focus. "The more complex your mind-wandering episode is, the more of your mind it's going to consume," Smallwood says.

Defects in the default network may also impair our ability to daydream. A range of disorders—including schizophrenia and depression—have been linked to malfunctions in the default network. In a 2007 study neuroscientist Peter Williamson of the University of Western Ontario found that people with schizophrenia have deficits in the medial prefrontal cortex, which is associated with self-reflection. In patients experiencing hallucinations, the medial prefrontal cortex dropped out of the network altogether. Although the patients were thinking, they could not be sure where the thoughts were coming from. People with schizophrenia daydream normally most of the time, but when they are ill, "they often complain that someone is reading their mind or that someone is putting thoughts in their head," Williamson says.

On the other hand, those who ruminate obsessively—rehashing past events, repetitively analyzing their causes and consequences, or worrying about all the ways things could go wrong in the future—are well aware that their thoughts are their own, but they have intense difficulty turning them off. The late Yale psychologist Susan Nolen-Hoeksema did not believe that rumination is a form of daydreaming, which she defined as "imagining situations in the future that are largely positive in tone." Nevertheless, she found that in obsessive ruminators, who are at greater risk of depression, the same default network circuitry turns on that is activated when we daydream.

"WHAT WE FIND IS THAT THE PEOPLE WHO REGULARLY CATCH THEMSELVES [DAYDREAMING]—WHO NOTICE WHEN THEY'RE DOING IT—**SEEM TO BE THE MOST CREATIVE**," ONE PSYCHOLOGIST SAYS.

These ruminators—who may repeatedly scrutinize faux pas, family issues or lovers' betrayals—have trouble switching off the default network when asked to focus mentally on a neutral image, such as a truckload of watermelons. They may spend hours going over some past incident, asking themselves how it could have happened and why they did not react differently and end up feeling overwhelmed instead of searching for solutions. Experimental studies have shown that positive distraction—for example, exercise and social activities—can help ruminators reappraise their situation, as can tech-

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Daydreaming can serve as a useful distraction. For example, conjuring up soothing scenes from the past could make a visit to the doctor more bearable.

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niques for cultivating mindfulness that teach individuals to pay precise attention to activities such as breathing or walking rather than to thoughts. Yet people who daydream excessively may have the same problems ignoring their thoughts once they get going. Indeed, extreme daydreamers find their private world so difficult to escape that they describe it as an addiction—one as enslaving as heroin.

When Daydreaming Becomes a Drug

"I'm like an alcoholic with an unlimited supply of booze everywhere I go," says Cordellia Amethyste Rose, of Oregon, who started an online forum called Wild Minds (http://wildminds.ning.com) for people who simply cannot stop daydreaming. Since childhood, Rose has conjured up countless imaginary characters in ever changing plots. "They've grown right along with me, had children—some have died," she says. The deeper she delved into her virtual world, though, the more distressed she became. "I couldn't pay attention for more than a split second. I would look at a book and zone out after every word." Even so, she found her invented companions more compelling than anyone real. "I've learned to socialize internally with fictional characters I get along with," she says. She could engage them in intellectual debate, whereas "socializing with outside people frustrates me. They all want to talk about the silliest things."

Rose says that she has no friends, but on Wild Minds she has found her peers. Many people posting to the site express relief that they have found others like themselves, emerging from a cocoon of loneliness and shame to share their experiences: misdiagnoses, lack of understanding from families and therapists, and rituals like the one described by a quiet girl who spends "endless hours" swaying in a rocking chair listening to music, daydreaming her life away. "It's like a drug, poisoning and destroying your life," says one anonymous fantasist, who admits to bingeing for days on a story line. "It's even worse because an addict can put a drug down and walk away. You can't put down your mind and walk away from it."

Yet few of the members of the Wild Minds community would abandon their mental creations, even if they could. One hardworking nurse revels in imagined adventures starring a fictional medieval Queen Eleanor of Scotland, a skilled horsewoman with four concurrent husbands, who practices a made-up religion and is "a genius in both state and battlecraft … trained in martial arts and is always inventing marvelous things." Like Thurber's fictional fantasist, Queen Eleanor's creator spends a lot of time mentally rescuing disaster victims from burning buildings or "abseiling over cliffs, being winched in and out of helicopters with casualties."

She has also documented her fantastical plots for independent biopsychologist Cynthia Schupak, a researcher with a single-minded mission to understand compulsive daydreamers, who treated Rachel Stein and described her ordeal in a journal article published in 2009. Schupak is convinced that compulsive daydreaming is a unique disorder, characterized by an inability to control it and the deep distress over the condition. "Everyday escapist fantasy is fine and dandy, but this syndrome is different," she says.

In 2011 Schupak and psychology researcher Jayne Bigelsen published a study

A pleasant reverie about a successful acting career might motivate you to work hard for a desired outcome, but it could be detrimental if you become oblivious to pickpockets or vehicular traffic.

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"I'M LIKE AN ALCOHOLIC WITH AN UNLIMITED SUPPLY OF BOOZE WHEREVER I GO," SAYS CORDELLIA AMETHYSTE ROSE, WHO STARTED AN ONLINE FORUM **FOR PEOPLE WHO CANNOT STOP DAYDREAMING.**

of 90 compulsive fantasizers—75 women and 15 men—garnered from Web sites such as the Yahoo group Maladaptive Daydreamers (http://health.groups.yahoo.com/group/maladaptivedaydreamers). The self-selected respondents devoted between 12.5 and 99 percent of their waking hours to daydreaming, and 79 percent of them engaged in physical movement such as pacing while doing so. Many said everyday activities paled by comparison with their vivid inner worlds, and some drifted in and out of their alternative reality in the midst of conversation. Typically they reported that their daydreams made them feel comforted or confident "because it's me, just magnified," as one subject put it. Nevertheless, 88 percent said they anguished over the amount of time spent fantasizing, even though most were gainfully employed or students. Nine percent had no friends or meaningful relationships, and 82 percent kept their daydreaming habit hidden from almost everyone.

Some evidence suggests that maladaptive daydreaming could be a distinctive disorder. About a decade ago clinical psychologist Eli Somer of the University of Haifa in Israel recounted cases of six people consumed by fantasy lives packed with sadism and bloodshed. All had suffered some form of childhood trauma. One had been sexually molested by her grandfather. Another described his father as a brutal man who humiliated and physically abused family members.

Somer believes that this mental activity emerged as a coping mechanism to help his patients deal with intolerable or inescapable realities. When their enhanced ability to conjure up vivid imagery is under control and does not interfere with social or academic success, "the phenomenon should probably be classified as a talent rather than a disorder," he says. Attitude may also be important.

Yale University's Singer, who grew up during the Great Depression and had no formal musical training, says he entertained himself through childhood and adolescence with the imaginary achievements of "Singer the Composer," an alter ego who wrote a complete repertoire of classical music, including operas and an unfinished Seventh Symphony. He does not consider his inner adventures harmful but rather sees them as a boredom-banishing sport—one that likely helped to propel him into his profession.

Is Your Mind Wandering Out of Control?

How do you know when you have tipped over from useful and creative daydreaming into the netherworld of compulsive fantasizing? First, notice whether you are deriving any useful insights from your fantasies. "The proof is in the pudding," Schooler says. "Creative individuals—artists, scientists, and so on—oftentimes report ideas that have occurred to them during daydreams." Second, it is important to take stock of the content of your daydreams. To distinguish between beneficial and pathological imaginings, he adds, "Ask yourself if this is something useful, helpful, valuable, pleasant, or am I just rehashing the same old perseverative thoughts over and over again?" And if daydreaming feels out of control, then even if it is pleasant it is probably not useful or valuable.

Whether or not mind wandering causes distress often depends on the context, Kane observes. "We argue that it's not inherently good or bad; it all depends on what the goals of the person are at the time." It may be perfectly reasonable for a scientist to mentally check out in the midst of a repetitive experiment. And a novelist who can publish her reveries is clearly putting them to good use.

"Happily, a lot of what we do in life doesn't require that much concentration," Kane says. "But there are going to be some contexts in which it is costly. Does the cost to your activity, to your reputation, to your performance, overwhelm the benefit that you may be getting from those thoughts? You can imagine situations where it is so costly that there's no thought you could be having that's worth it," he says, pausing to consider the possibilities. "You've crossed the line," Kane concludes, "if you walk into traffic and get killed." M

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THE SERIOUS NEED FOR PLAY

FREE, IMAGINATIVE PLAY IS CRUCIAL FOR NORMAL SOCIAL, EMOTIONAL AND COGNITIVE DEVELOPMENT. IT MAKES US BETTER ADJUSTED, SMARTER AND LESS STRESSED

By Melinda Wenner Moyer
Photograph by Aaron Goodman

FAST FACTS
GO AHEAD, HORSE AROUND

1. Childhood play is crucial for social, emotional and cognitive development.
2. Imaginative and rambunctious "free play," as opposed to games or structured activities, is the most essential type.
3. Kids and animals that do not play when they are young may grow into anxious, socially maladjusted adults.

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On August 1, 1966, the day psychiatrist Stuart Brown started his assistant professorship at the Baylor College of Medicine in Houston, 25-year-old Charles Whitman climbed to the top of the University of Texas Tower on the Austin campus and shot 46 people. Whitman, an engineering student and a former U.S. Marine sharpshooter, was the last person anyone expected to go on a killing spree. After Brown was assigned as the state's consulting psychiatrist to investigate the incident and later, when he interviewed 26 convicted Texas murderers for a pilot study, he discovered that most of the killers, including Whitman, shared two things in common: they were from abusive families, and they never played as kids.

Brown did not know which factor was more important. But in the 50 years since, he has interviewed more than 6,000 people about their childhoods, and his data suggest that a lack of opportunities for unstructured, imaginative play can keep children from growing into happy, well-adjusted adults. "Free play," as scientists call it, is critical for becoming socially adept, coping with stress and building cognitive skills such as problem solving. Research into animal behavior confirms play's benefits and establishes its evolutionary importance.

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When animals play, their body language signals that any nipping or tumbling is meant to be friendly and fun. Play similarly teaches kids to better communicate with one another.

Most psychologists agree that play affords benefits that last through adulthood, but they do not always agree on the extent to which a lack of play harms kids—particularly because, in the past, few children grew up without ample frolicking time. But today free play may be losing its standing as a staple of youth. According to a paper published in 2005 in the *Archives of Pediatrics & Adolescent Medicine,* children's free-play time dropped by a quarter between 1981 and 1997. Concerned about getting their kids into the right colleges, parents are sacrificing playtime for more structured activities. As early as preschool, youngsters' after-school hours are now being filled with music lessons and sports—reducing time for the type of imaginative and rambunctious cavorting that fosters creativity and cooperation. Free play has been sacrificed at school, too. According to a 2007 survey conducted by the Center on Education Policy, 20 percent of 349 American elementary public school districts had decreased their recess time since 2001.

A handful of studies have supported Brown's conviction that a play-deprived childhood disrupts normal social, emotional and cognitive development in humans and animals. He and other psychologists worry that limiting free play in kids may result in a generation of anxious, unhappy and socially maladjusted adults. "The consequence of a life that is seriously play-deprived is serious stuff," Brown says. But it is never too late to start: play also promotes the continued mental and physical well-being of adults [*see box on page 83*].

Worries over the demise of play began surfacing as far back as 1961, when the International Play Association was founded in Denmark to protect, preserve and promote play as a fundamental right for all children. But the idea became more popular in the past few decades, when many more nonprofit foundations—such as the National Institute for Play in Carmel Valley, Calif., started by Brown, and other organizations, including the Alliance for Childhood and the Association for the Study of Play—began forming to promote the value of play.

Freedom Counts

But kids *play* soccer, Scrabble and the sousaphone—so why are experts concerned that these activities are eating into free play? Certainly games with rules are fun and are sources of learning experiences—they may indeed foster better social skills and group cohesion, for instance, says Anthony D. Pellegrini, an educational psychologist at the University of Minnesota. But, Pellegrini explains, "games have a priori rules—set up in advance and followed. Play, on the other hand, does not have a priori rules, so it affords more creative responses."

This creative aspect is key because it challenges the developing brain more than following predetermined rules does. In free play, kids initiate and create new activities and roles. It might involve fantasies—such as pretending to be doctors or princesses—or it might include mock fighting, as when kids (primarily boys) wrestle with one another for fun, switching roles periodically so that neither of them always wins. And free play is most similar to play seen in the animal kingdom, suggesting that it has important evolutionary roots. Gordon M. Burghardt, author of the 2005 *The Genesis of Animal Play,* spent 18 years observing animals to learn how to define play: it must be repetitive—an animal that nudges a new object just once is not

STUDIES SHOW THAT **CHILDREN USE MORE SOPHISTICATED LANGUAGE WHEN PLAYING WITH OTHER CHILDREN** THAN WHEN PLAYING WITH ADULTS. THEY HAVE TO PROVIDE CONTEXTUAL CLUES.

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Dressing up and pretending to be someone else is a type of "free play," as psychologists call it—the unstructured, imaginative fun that is most challenging to the developing brain.

playing with it—and it must be voluntary and initiated in a relaxed setting. Animals and children do not play when they are undernourished or in stressful situations. Most essential, the activity should not have an obvious function in the context in which it is seen—meaning that it has no clear goal.

Face Time

How do these seemingly pointless activities benefit kids? Perhaps most crucially, play appears to help us develop strong social skills. "You don't become socially competent via teachers telling you how to behave," Pellegrini says. "You learn those skills by interacting with your peers, learning what's acceptable, what's not acceptable." Children learn to be fair and take turns—they cannot always demand to be the fairy queen, or soon they have no playmates. Also, because kids enjoy the activity, they do not give up as easily in the face of frustration as they might on, say, a math problem—which helps them develop persistence.

Keeping things friendly requires a fair bit of communication—arguably the most valuable social skill of all. Play that transpires with peers is the most important in this regard. Studies show that children use more sophisticated language when playing with other children than when playing with adults. In pretend play, for instance, "they have to communicate about something that's not physically present, so they have to use complicated language in such a way that they can communicate to their peers what it is that they're trying to say," Pellegrini says. For example, kids can't get away with just asking, "Vanilla or chocolate?" as they hand a friend an imaginary cone. They have to provide contextual clues: "Vanilla or chocolate ice cream: Which one would you like?" Adults, on the other hand, fill in the blanks themselves, making things easier for kids.

If play helps children become socialized, then lack of play should impede social development—and studies suggest that it does. According to a 1997 study of children living in poverty and at high risk of school failure, published by the HighScope Educational Research Foundation in Ypsilanti, Mich., kids who enrolled in play-ori-

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BY AGE 23, MORE THAN ONE THIRD OF **KIDS WHO HAD GONE TO PLAY-FREE PRESCHOOLS HAD BEEN ARRESTED FOR A FELONY** AS COMPARED WITH FEWER THAN ONE TENTH OF PLAY-ORIENTED PRESCHOOL ALUMS.

ented preschools are more socially adjusted later in life than are kids who attended play-free preschools where they were constantly instructed by teachers. By age 23, more than one third of kids who had attended instruction-oriented preschools had been arrested for a felony as compared with fewer than one tenth of the kids who had been in play-oriented preschools. And as adults, fewer than 7 percent of the play-oriented preschool attendees had ever been suspended from work, but more than a quarter of the directly instructed kids had.

Animal studies lend support to the idea that play deprivation leads to poor social skills. According to a study published in 1999 in *Behavioural Brain Research,* rats that are kept isolated during the two weeks of development when they most frequently play—the fourth and fifth weeks after birth—are much less socially active when they later encounter other rats as compared with rats that are not isolated during the same two-week period. And a study that was published in 2002 in *Developmental Psychobiology* revealed that male rats reared in isolation during their youth fail to display normal avoidance behaviors when introduced to dominant male rats that repeatedly attack them. Could play deprivation specifically cause these behavioral problems—or could social isolation in general have been the culprit?

Another study suggests that play promotes neural development in "higher" brain areas involved in emotional reactions and social learning. Scientists reported in 2003 that play fighting releases brain-derived neurotrophic factor (BDNF)—a protein that stimulates the growth of new neurons—in these regions. The researchers allowed 13 control rats to play freely with companions for three and a half days and kept 14 other rats isolated for the same period. On examining the rats' brains, the researchers found that the cortex, hippocampus, amygdala and pons of the rats that had played contained much higher levels of BDNF than those of the rats that had not. "I think play is the major mechanism whereby higher regions of the brain get socialized," says Washington State University neuroscientist Jaak Panksepp, who co-authored the study.

Stress Relief

Research suggests that play is also critical for emotional health, possibly because it helps kids work through anxiety and stress. In a 1984 study pub-

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Many children (especially boys) like to engage in mock fighting, or rough-and-tumble play. Such roughhousing has been shown to improve creativity, social skills and problem-solving abilities.

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lished in the *Journal of Child Psychology and Psychiatry*, researchers assessed the anxiety levels of 74 three- and four-year-old children on their first day of preschool as indicated by their behavior—whether they pleaded, whined and begged their parents to stay—and how much their palms were sweating. Based on the researchers' observations, they labeled each child as either anxious or not anxious. They then randomly split the 74 kids into four groups. Half of the kids were escorted to rooms full of toys, where they played either alone or with peers for 15 minutes; the other half were told to sit at a small table either alone or with peers and listen to a teacher tell a story for 15 minutes.

Afterward, the kids' levels of distress were assessed again. The anxiety levels of the anxious kids who had played had dropped by more than twice as much as compared with the anxious kids who had listened to the story. (The kids who were not anxious to begin with stayed about the same.) Interestingly, those who played alone calmed down more than the ones who played with peers. The researchers speculate that through imaginative play, which is most easily initiated alone, children build fantasies that help them cope with difficult situations.

Animal studies also support the idea that play helps to alleviate stress—a concept known in neuroscience as social buffering. In a study published in 2008, Gettysburg College neuroscientist Stephen Siviy put rats into a chamber by themselves and exposed them to a collar previously worn by a cat, which made them visibly anxious. Later, the chamber was cleaned so it no longer smelled of the cat, the rats were put back in without the cat collar, and the rats immediately became anxious again, probably because they associated the space with the cat. But if Siviy

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ALL WORK AND NO PLAY . . .

Although researchers usually emphasize the positive effect of play on the developing brain, they have found that play is important for adults, too. Without play, adults may end up getting burned out from the "hustle-bustle busyness that we all get involved in," says Marc Bekoff, an evolutionary biologist at the University of Colorado Boulder. Adults who do not play may end up unhappy and exhausted without understanding exactly why.

So how can adults get more play into their lives? Stuart Brown, psychiatrist and founder of the National Institute for Play in Carmel Valley, Calif., suggests three ways:

>> BODY PLAY

Participate in some form of active movement that has no time pressures or expected outcome (if you are exercising just to burn fat, that is not play!).

>> OBJECT PLAY

Use your hands to create something you enjoy (it can be anything; again, there doesn't have to be a specific goal).

>> SOCIAL PLAY

Join other people in seemingly purposeless social activities, "from small talk to verbal jousting," Brown suggests.

If you are still not sure what to do, try to remember what you enjoyed doing as a child. "Find your childhood play's 'true north'" and try to translate those memories into activities that fit the current circumstances, Brown says. You might even spark your memory better if you spend a little time around kids, notes Gordon M. Burghardt, an evolutionary biologist at the University of Tennessee.

Ultimately what matters is not *how* you play but *that* you play. And to make sure you do, schedule time in your day for it, Bekoff suggests. "Work will always get done," he says. "In fact, I know that if I don't play, I really don't get more work done." And, Burghardt adds, the happiness and renewed energy you will experience from playing will "more than compensate for the time 'lost.'" —*M.W.M.*

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One study found that kids who played with blocks scored higher on language tests than kids who had no blocks. Perhaps the children with blocks simply spent less time on activities such as watching TV—but the end result was good for them in any case.

and his colleagues then introduced another rat into the chamber—one that had never been exposed to the cat collar and was not afraid—the two would begin playing by chasing each other, tumbling and pretend fighting. And shortly thereafter, the first rat would relax and become calm, suggesting that play helped the rat to lessen its anxiety.

Play to the Head of the Class

Relieving stress and building social skills may seem to be obvious benefits of play. But research hints at a third, more counterintuitive area of influence: play actually appears to make kids smarter. In a classic study published in 1973 in *Developmental Psychology,* researchers divided 90 preschool children into three groups. One group was told to play freely with four common objects—among the choices were a pile of paper towels, a screwdriver, a wood board and a pile of paper clips. A second set was asked to imitate an experimenter using the four objects in common ways. The last group was told to sit at a table and draw whatever they wanted, without ever seeing the objects. Each scenario lasted 10 minutes. Immediately afterward, the researchers asked the children to come up with ideas for how one of the objects could be used. The kids who had played with the objects named, on average, three times as many nonstandard, creative uses for the objects than the youths in either of the other two groups did, suggesting that play does foster creative thinking.

Play fighting also improves problem solving. According to a paper published in 1989 by Pellegrini, the more elementary school boys engaged in roughhousing, the better they scored on a test of social problem solving. During the test, researchers presented kids with five pictures of a child trying to get a toy from a peer and five pictures of a child trying to avoid being scolded by his mother. The subjects were then asked to come up with as many possible solutions to each social problem; their score was based on the variety of strategies they mentioned, and children who play-fought regularly tended to score much better.

Pellegrini does question, however, how much cause and effect one can glean from these studies. "What does play do? Is it the vanguard of learning something—so does play precede those sorts of skills—or is it merely practice or consolidation of skills that are already developing?" he asks. In 2012 researchers at the University of Virginia analyzed the scientific literature and concluded that play could simply be a sign of healthy development or, alternatively, that it might be one of many activities that makes a difference to the developing brain. But Pellegrini maintains that "either way, at some level, it would be beneficial."

Does lack of play, then, impede the development of problem-solving skills? Perhaps, according to animal studies. In a paper published in 1978 in *Developmental Psychobiology,* experimenters separated young rats by mesh partitions—they could see, smell and hear other rats but could not play with them—for the 20 days during development when they would have most frequently played. The researchers taught these rats, and a group that had been allowed to play without constraints, to pull a rubber ball out of the way to get a food treat. A few days later they switched the setup so the rats would have to push the same ball to get the treat. The isolated rats took much longer to try new approaches, and thus solve the problem, than did the rats that had played. The authors speculate that through play, animals learn to try new things, and those that do not play simply do not acquire this same behavioral flexibility.

THROUGH PLAY, ANIMALS LEARN TO TRY NEW THINGS. ANIMALS THAT DO NOT PLAY SIMPLY DO NOT ACQUIRE THIS SAME BEHAVIORAL FLEXIBILITY.

JUPITERIMAGES

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Far from engaging in mindless destruction, children who explore everyday objects by playing with them in unusual (albeit sometimes messy) ways are developing their creativity.

ply do not acquire this same behavioral flexibility.

Playing also appears to help with language development, according to a 2007 study in the *Archives of Pediatrics & Adolescent Medicine*. Researchers at the University of Washington gave a box of toy blocks to children from middle- and low-income families aged 18 months to two and a half years. Parents of these kids, as well as parents of a similar group of kids who had no blocks, kept track of how often the children played. After six months, the kids who had played with blocks scored significantly higher on language tests than the others did. But why might play help kids excel?

Animal researchers believe that play serves as a kind of training for the unexpected. "Play is like a kaleidoscope," says evolutionary biologist Marc Bekoff of the University of Colorado Boulder, in that it is random and creative. The bottom line, he posits, is that play encourages flexibility and creativity that may, in the future, be advantageous in unexpected situations or new environments. Some child psychologists, such as Tufts University child development expert David Elkind, agree. Play is "a way in which children learn," Elkind points out, "and in the absence of play, children miss learning experiences."

Let Loose

If play is so crucial, what happens to children who are not playing enough? Ultimately no one knows—but many psychologists are worried. Because play is somewhat risky—animals that are not alert and watchful are at risk of being attacked by predators—it probably evolved and persists because it confers survival advantages. "If it wasn't important, it wouldn't have evolved in its elaborate form," Bekoff says.

Indeed, evidence indicates that play is evolutionarily quite ancient. Rats that have had their neocortex removed—a large brain region that is involved in higher-order thinking such as conscious thought and decision making—still engage in normal play, which suggests that play motivation comes from the brain stem, a structure that precedes the evolution of mammals.

Of course, many parents today believe they are acting in their kids' best interests when they swap free play for what they see as valuable learning activities. Some mothers and fathers may also hesitate to let their sons and daughters play outside unattended, and they may fret about the possibility of the scrapes and broken bones that sometimes arise during rambunctious play, says Sergio M. Pellis, a behavioral neuroscientist at the University of Lethbridge in Alberta. Although those parental instincts are natural, protecting youngsters "simply defrays those costs to later, when those same children will have difficulty in dealing with an unpredictable, complex world," Pellis says. A 2015 systematic review reported that risky outdoor play—climbing on high playground structures, for instance, or engaging in rough-and-tumble play—was associated with better physical health among kids, not worse, and that it was also linked to greater creativity and resilience.

Parents should let children be children—not just because it should be fun to be a child but because denying youth's unfettered joys keeps kids from developing into inquisitive, creative creatures, Elkind warns. "Play has to be reframed and seen not as an opposite to work but rather as a complement," he says. "Curiosity, imagination and creativity are like muscles: if you don't use them, you lose them." M

MORE TO EXPLORE

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- **Play = Learning: How Play Motivates and Enhances Children's Cognitive and Social-Emotional Growth.** Edited by Dorothy G. Singer, Roberta Michnick Golinkoff and Kathy Hirsh-Pasek. Oxford University Press, 2006.
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CORBIS

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YOUR FERTILE BRAIN AT WORK

SCIENTISTS HAVE MAPPED THE INNOVATIVE MIND SO THAT WE CAN REMAKE OUR OWN IN ITS IMAGE

By Evangelia G. Chrysikou

Illustration by MCKIBILLO

FAST FACTS

BREAKING THE RULES

❶ Innovation matters in an enormous variety of professions. It elevates the careers of chefs, university presidents, psychotherapists, police detectives, journalists, teachers, engineers, architects, attorneys and surgeons, among other professionals.

❷ Although creativity was long considered a gift of a select minority, psychologists have now revealed its seeds in mental processes—such as decision making, language and memory—that all of us possess.

❸ Techniques for boosting creative potential may involve breaking down established ways of viewing the world or invoking unconscious thought processes.

During the July 4th weekend of 1994, while riding in a 1988 Chevy Blazer with his wife at the wheel, a computer engineer named Jeff Bezos laid the groundwork for a retail revolution. Back then, the Internet was an insider's tool, largely limited to government and academic circles. But after months of careful observation of its usage, Bezos envisioned a dramatic expansion of this network, one that would bring it into the daily lives of ordinary people. In the car, he sketched out a business plan for a project that would realize his vision: the Internet, he understood, could boost the efficiency of mail-order businesses, starting with books.

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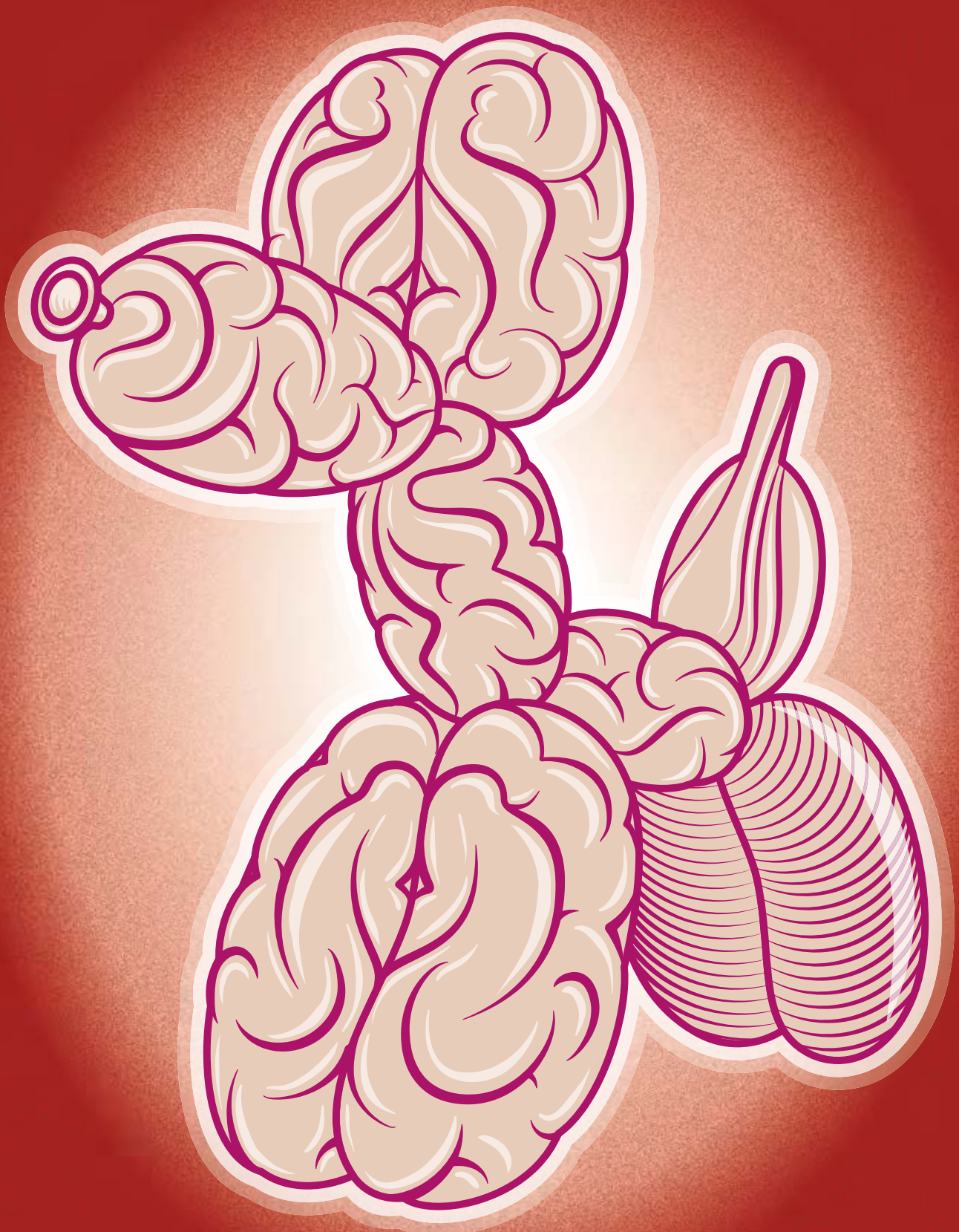

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In a risky move, Bezos and his wife, Mackenzie, left lucrative jobs in New York's financial sector to build an Internet-based bookseller headquartered in Seattle. They called it "Amazon," after the interminable South American river and its many branches. After a few months of testing and without any advertising, the company started racking up $20,000 weekly in sales. In just a few years Amazon was worth billions. Bezos forever changed how people purchase goods and made a lasting impact on the business world.

For entrepreneurs worldwide, Amazon.com is a model of innovation. Yet creativity can come in many forms. Consider Procter & Gamble's line of Swiffer products: a reconceptualization of mops, sweepers and dusters based on the simple insight that cleaning with disposable parts makes the job easier and more fun. Designer Gianfranco Zaccai of Herman Miller and his team are credited with inventing Swiffer, which reaps more than $500 million in annual sales.

Innovation matters in an enormous variety of professions. It elevates the careers of chefs, university presidents, psychotherapists, police detectives, journalists, teachers, engineers, architects, attorneys and surgeons, among other professionals. The contributions of creative thought can directly translate into career advancement as well as financial rewards. In an unfavorable economic climate, raising your creative game may even mark the difference between survival and failure.

Psychologists broadly define creativity as the purposeful generation and implementation of a novel idea. In the workplace, it may be more aptly characterized as the effortful pursuit and implementation of novelty that results in measurably useful outcomes. In numerous studies over the past few decades psychologists have tried to unravel the mysteries of exceptional creativity in the arts or sciences, considering the likes of Pablo Picasso, Mozart, Virginia Woolf, the Wright brothers and Albert Einstein. These investigations, along with others into the origins of everyday problem solving, have uncovered genetic, social and economic factors (as well as lucky circumstances) that contribute to creative thought.

Although creativity has long been considered a gift of a select minority, psychologists are now revealing its seeds in mental processes, such as decision making, language and memory, that all of us possess. Thus, we can all boost our creative potential. Recent studies have shown promise for techniques that break down people's established ways of viewing the world as well as strategies that encourage unconscious thought processes. Read on to try these at home—or at work.

An Open Mind

Iconic individuals such as Bezos, the late Steve Jobs, Martha Stewart, Steve Ells (founder of Chipotle Mexican Grill restaurants) and many others have inspired entrepreneurs and professionals to hone their creative skills. Individuals and companies have typically used creativity workshops, brainstorming sessions, self-help books, training videos and even hypnosis as vehicles for such improvement. Whether such practices influence the likelihood of creative leaps is unknown. Yet psychologists and neuroscientists have made some important discoveries that can help us understand the states of mind that benefit creative thought.

INNOVATIVE IDEAS CAN ARISE FROM PAYING ATTENTION TO THE VISUAL PROPERTIES OF THINGS, SUCH AS THEIR SHAPE AND SIZE.

When people consider creativity, they generally think of the birth of novel ideas. Idea generation is indeed the first important stage of the creative process. To come up with new ideas for achieving a goal, you need, roughly speaking, an open mind—that is, one guided by minimal rules and constraints. In 2009 neuroscientist Sharon Thompson-Schill of the University of Pennsylvania and her colleagues proposed that creative inspiration might benefit from a state of lower cognitive control—that is, fewer restrictions on your thoughts and behavior.

Your more prosaic, rule-guided thought is associated with a burst of activity in your prefrontal cortex, a region on the surface of the brain behind your forehead that regulates your decisions, thoughts and actions. When you abandon rules or blur your attentional focus, this region quiets down. Thompson-Schill's team called this resulting state hypofrontality and hypothesized that it holds various benefits for language learning and creative thought, among other aspects of cognition.

Researchers found early hints of hypofrontality in the mid-1990s, when they measured the electrical activity in the brains of people who were generating new ideas. By picking up electrical waves on the scalp, scientists can get a sense of a person's "brain state," say, awake or asleep, focused or relaxed.

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When someone is engaged in a task that requires cognitive control and focused attention—for instance, solving a math problem or deciding what to pack for a camping trip—so-called beta waves, which oscillate at a frequency of 15 to 20 hertz, usually dominate. When people came up with new ideas, however, researchers recorded alpha waves over the prefrontal cortex. These eight- to 12-hertz waves are typically a sign of relaxed wakefulness and diffuse attention. Their presence thus bolstered the notion that idea generation is associated with a state of lower cognitive control.

The behavior of patients whose frontal lobes have partially degenerated as a result of frontotemporal dementia or similar disorders is consistent with this view. These individuals show severe impairments in regulating their thoughts and actions but may experience spontaneous musical or artistic creativity they lacked before they got sick. [For more on the link between creative thinking and unconventional behavior, see "The Unleashed Mind," by Shelley Carson, on page 28.]

More recent data strengthen the case for the importance of hypofrontality in everyday creativity. In a study published in 2011 Thompson-Schill and I showed participants pictures of ordinary objects (tissues, for example) and asked them to tell us either a common use (wiping your nose) or an uncommon application (protective stuffing for a package) for each one. Participants who came up with unusual uses for the items showed minimal activity in prefrontal brain regions and heightened activity in posterior brain regions that are typically in charge of visuospatial skills. In contrast, those who thought of typical uses showed the reverse pattern. Thus, generating novel applications for objects also seems to benefit from less filtering of knowledge and experiences, which enables people to consider a greater variety of possible answers.

What is more, innovative ideas can arise from paying attention to the visual properties of things, such as their shape, size and material makeup. Instead of highlighting previous knowledge, the brain enters a state that emphasizes often overlooked perceptual elements.

Scientists have been able to mimic this brain state by applying electrical stimulation to the scalp and thereby improving problem-solving ability. These data lend considerable credence to the idea that diminished activity in the prefrontal cortex, particularly on the left side of the brain, underlies an important part of the creative process [*see box on page 91*].

Generating novel applications for objects—such as this use of sticky notes in a mural—seems to benefit from less filtering of knowledge and experiences. A more porous mental filter enables us to consider a greater variety of possible solutions.

COURTESY OF PETER HELLBERG

Thought Control

In addition to idea generation, true creativity involves evaluating your options, picking the best one and implementing a plan for realizing your vision. This evaluation process, the second critical stage of creative thought, involves a mental state in which the cognitive filter in the prefrontal cortex is on instead of off. In a study published in 2011 psychologist Kalina Christoff of the University of British Columbia and her colleagues asked college students from the Emily Carr University of Art + Design in Vancouver to generate illustrations for book covers on a special drawing tablet while inside a brain scanner. The students were asked to come up with ideas for their sketches for 30 seconds and then

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If you are struggling with a difficult project at work, take a break. The recess may shake loose some creative thoughts, especially if you choose to do something dramatically different from what your job entails.

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spend 20 seconds evaluating what they had sketched. The researchers found that the prefrontal cortex, among other regions, was more active during the evaluation stage, suggesting that the executive-control network that filters data and exerts brakes on behavior is more engaged during the evaluative phase of the creative process.

Creative individuals may thus be those who are better able to upregulate or downregulate their cognitive-control system depending on the demands of the situation—a skill known as cognitive flexibility. In a 2010 study Darya Zabelina and Michael Robinson, both then at North Dakota State University, first assessed the creativity of 50 undergraduate students using standard paper-and-pencil tests and then measured their capacity for cognitive control with the Stroop task. In this task, people are given a list of color words ("yellow," "blue," "red," and so on) that are typed in a color that often does not match the word. The goal is to state the color of the word regardless of what the word says. The task measures how well a person can filter out irrelevant information to focus on what is important, a major feature of cognitive control.

Although creative and noncreative subjects performed equally well on this task overall, creative subjects did better every time they had to switch from a matching combination (for instance, the word "red" appearing in red type) to a clashing one ("red" showing up in blue letters). These results indicate that creative people show greater cognitive flexibility, which can support the ability to both generate novel ideas and put these ideas into action.

Psychologists have been exploring ways to expand our creativity, enhancing the arsenal of techniques that promote idea generation and implementation. Some of these methods appear in the sections that follow.

Mental Push-ups

Exercises that shake up people's typical ways of thinking can help put them in a creative mindset. A version of the alternative-uses task described earlier, for example, can get people to rethink the way they categorize objects. In a study published in 2006 my colleagues and I asked college students to devise up to six alternative uses for 12 common objects in 15 minutes. Then we asked them to solve practical problems, such as affixing a candle upright on a wall using a book of matches and a box of tacks. (Hint: think of the box as a platform.)

For some of the students, the objects in the first task were related to the practical problems; for others, they were not. These two groups did equally well on the practical problems, however, and both solved significantly more of them than did students who had not completed the alternative-uses task. Thus, the training task seemed to benefit our subjects more generally, putting them in the right state of mind for creative problem solving.

Another method for boosting creativity might be to describe objects in unusual ways—for example, in terms of their features rather than their function. In a 2012 study psychologist Tony McCaffrey of the University of Massachusetts Amherst trained students to define objects generically by their shape, size and materials. A candle might be described as wax and wick or, even more obscurely, as string and cylindrically shaped lipids. McCaffrey encouraged the students to ask themselves, "Can I break the description down any further?" and "Does my description imply a particular use?" Participants who received this training showed a 67 percent boost in problem-solving performance relative to those who did not. One reason for their advantage: they were more likely to notice obscure features of the problems that were necessary for their solution.

Performing common tasks in an unconventional order can also upset your ordinary thought processes and thereby raise your creative prospects. In a 2012 study psychologist Simone Ritter of Rad-

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TICKLING THE BRAIN

Neuroscientists have been able to tweak the creative process by enhancing or suppressing activity in frontal brain regions. In a technique called transcranial direct-current stimulation, minute amounts of electric current flow through a pair of electrodes affixed to the scalp and thereby either raise or lower activity in the underlying brain regions.

In a study published in 2011 neuroscientist Allan W. Snyder of the Center for the Mind in Sydney and his colleagues used this method to affect the ability of individuals to solve arithmetic puzzles involving matchsticks (*below*). The initial problems could all be solved using a similar strategy, but the last two required abandoning what had worked before and developing a novel approach. Snyder's team hypothesized that the right hemisphere enhances creativity, whereas the left hemisphere impedes it. Indeed, when the researchers depressed activity in the left frontal cortex while exciting the right frontal cortex in some of their subjects, these individuals solved the last two problems at higher rates than those who received the opposite pattern of stimulation (left excitation, right inhibition) or sham stimulation.

Beyond fostering alternative problem-solving strategies, this neurostimulation technique can also support the generation of novel ideas, such as finding new uses for objects. In a 2013 study my colleagues and I inhibited neural activity in the left prefrontal cortex of participants while they came up with a common or an uncommon use for objects presented to them in pictures. These individuals thought of significantly *more* uncommon uses—and did so about a second faster—than did people who received inhibitory current over their right prefrontal cortex or those who were given sham stimulation. These results strongly support the hypothesis that blocking cognitive filtering by inhibiting the left prefrontal cortex during idea generation can promote creative thought.

—E.G.C.

TYPE	FALSE STATEMENT	SOLUTION
1	III=IX−I	III=IV−I
2	VI=VI+VI	VI=VI=VI
3	IX=VI−III	IX−VI=III

boud University Nijmegen and her colleagues asked a group of students to prepare a breakfast sandwich with butter and chocolate (a popular combination in the Netherlands). Half of them made the sandwich the regular way, and the rest were prompted to do so following an unusual sequence of steps. All the students were then given two minutes to generate uses for a brick and another two minutes to come up with as many answers as they could to the question "What makes sound?" Those who made the sandwich in an unconventional way—an activity that violated their expectations, the researchers theorized—came up with more different types of answers and thus scored higher on cognitive flexibility.

PEOPLE WHO MADE A SANDWICH IN AN UNCONVENTIONAL WAY CAME UP WITH MORE VARIED ANSWERS TO OPEN-ENDED QUESTIONS.

If mental exercises are not giving you enough good ideas, try enlisting your unconscious. One trick for achieving this mental power shift is to sleep on the problem. In particular, the stage of sleep known as rapid eye movement or dream sleep can help establish associations between remote ideas. These links may bring out solutions to conundrums that stumped you just before dozing off [see "Answers while You Sleep," by Deirdre Barrett, on page 58].

Similar benefits can come from letting your mind wander or deliberately distracting yourself. In a 2006 study psychologist Ap Dijksterhuis, also at Radboud University, and his colleagues asked people to generate novel names for products. Those who were sidetracked by a different task thought

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of more original names than those who worked on the problem continuously. In later studies, Dijksterhuis's team demonstrated that unconscious processing could yield answers to very difficult problems that require an extensive search of stored knowledge. These results suggest that if you are stuck on a difficult problem, it pays to take a break and do something else. [For more on the benefits of daydreaming, see "Living in an Imaginary World," by Josie Glausiusz, on page 70.]

What you do during your break turns out to be important, too. In a 2009 study psychologist Sophie Ellwood, then at the Center for the Mind in Sydney, and her colleagues asked participants to think of as many uses as they could for a piece of paper. Some performed the task continuously for four minutes; others paused after two minutes and did a similar exercise (thinking of synonyms for words) for five minutes before getting back to the paper task. A third group used the break to complete a personality questionnaire. The people who took a break generated more uses for the paper than those who were not interrupted, but those who did the unrelated activity performed the best on this creative task.

THOSE WHO SAW THEMSELVES IN THE DISTANT FUTURE SOLVED MORE PROBLEMS THAN THOSE WHO SIMPLY IMAGINED THE FOLLOWING DAY.

Keeping Your Distance

Many other social and emotional factors can spur creative thought. One of them is thinking of a problem as physically far away. Psychologist Lile Jia, then at Indiana University Bloomington, and his colleagues gave students practical problems similar to the one involving a candle discussed earlier. They told some participants that their responses would be collected for scientists at a university a few thousand miles away and others that a research team at their own university would get the results. A third group of students received no information about the study's whereabouts. Remarkably, the students who thought they were solving the problems for the faraway investigation solved twice as many problems as the other students. The researchers hypothesized that the psychological distance caused the students to approach the problems in more abstract terms, thereby facilitating their solution.

Distancing yourself in time can also promote innovation. Psychologist Nira Liberman of Tel Aviv University and her colleagues asked participants to imagine themselves either one day or one year in the future. Then the researchers gave their subjects a series of problems to solve and asked them to imagine themselves working on them on that future day. Those who pictured themselves in the distant future solved significantly more problems than those who simply imagined the following day.

Beyond psychological distance, physical dis-

AIM TO INNOVATE

Try these tips to maximize your creativity at work.

Become an expert. A solid knowledge base will allow you to connect remote ideas and see their relevance to a problem.

Observe. When trying to come up with a new product or service, carefully study how people use what is currently available and what problems they face.

Know your audience. Walk in the shoes of the intended consumer. How would a child use a remote control? How would an elderly person access a voting booth? How can I make this dessert for a vegan?

Step out of your comfort zone. Seek activities outside your field of expertise. Take a class; read a book; travel to a foreign country. New experiences often bring forth novel thoughts.

Be willing to work alone. Group brainstorming can help you synthesize your ideas, but it is far more effective if you have started the creative process on your own.

Talk to outsiders about your work. A novel perspective can help you see alternative solutions or possible faults with your original idea.

Have fun. A good mood can forge remote associations. Upbeat music may help but also makes tasks that demand focus more difficult. If you need to concentrate, dampen your demeanor with sad songs.

Take a nap or let your mind wander. Sleep and daydreaming can enlist your unconscious mind to work on a problem that is stumping you.

Take a break. Occupying your mind with a different task can unleash novel solutions.

Challenge yourself. Disrupt your daily routine. Abandon your initial idea (even if it works) and look for a new one. Borrow from other people's answers and try to improve on them.

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Working alone is usually the best way to come up with creative solutions. Once you have some ideas, casual interactions with others can help you develop them.

tance from others can also increase creative output. Despite its presumed benefits, group brainstorming is beneficial only after you have come up with a few solutions for a complex problem on your own, recent research has shown. In addition, brainstorming works better in the context of casual, brief semi-structured social interactions such as a lunch or social gathering than in long, organized meetings. Interactions among people with varied backgrounds—say, those who have different but related fields or those who work at other places—are especially good at promoting the synthesis and development of new ideas.

But no matter how imaginative our thoughts, we still must cross one major hurdle: our fear of risk. People tend toward safe routes, yet safety is not conducive to radical new solutions. Bezos and his wife not only had to come up with the notion of Amazon. They also had to be willing to cast off their current careers to pursue an uncertain future. Amid the financial and other practical and professional constraints of most workplaces, not to speak of other life concerns, abandoning a satisfactory but safe solution to pursue a new concept may be the biggest challenge to capitalizing on creative potential. As Bezos once said, "Innovation is disruption." M

MORE TO EXPLORE

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LET YOUR CREATIVITY SOAR

IN A DISCUSSION WITH *SCIENTIFIC AMERICAN* EDITOR IN CHIEF MARIETTE DiCHRISTINA, THREE NOTED EXPERTS ON CREATIVITY, EACH WITH A VERY DIFFERENT PERSPECTIVE AND BACKGROUND, REVEAL POWERFUL WAYS TO UNLEASH YOUR CREATIVE SELF

FAST FACTS

UNLEASHING CREATIVITY

❶ Creativity is not a gift from the muses only granted to certain people. Rather it is something that anyone can cultivate, using a variety of methods.

❷ The experts in a panel discussion offer simple ways to stimulate and capture new ideas—while countering negative thoughts and habits that block novel thinking.

❸ The lessons apply not only to adults: encouraging open-ended problem solving can help foster creativity in children as well.

MARIETTE DiCHRISTINA is editor in chief and senior vice president of *Scientific American*. She has been a journalist for more than 25 years.

JOHN HOUTZ is a psychologist and professor at Fordham University. His books include *The Educational Psychology of Creativity* (Hampton Press, 2002).

JULIA CAMERON is an award-winning poet, playwright and filmmaker. Her book *The Artist's Way* (Tarcher, 2002) has sold almost four million copies worldwide. She is also co-author of *It's Never Too Late to Begin Again* (TarcherPerigee, 2016).

ROBERT EPSTEIN is senior research psychologist at the American Institute for Behavioral Research and Technology, a contributing editor for *Scientific American Mind* and former editor in chief of *Psychology Today*. Epstein has written several books on creativity, including *The Big Book of Creativity Games* (McGraw-Hill, 2000).

COURTESY OF MARIETTE DiCHRISTINA, JOHN HOUTZ, JULIA CAMERON AND ROBERT EPSTEIN

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THE RIGHT TOOLS

ACCORDING TO EPSTEIN, THERE ARE FOUR "CORE COMPETENCIES" OF CREATIVE EXPRESSION. PEOPLE NEED TO LEARN TO PRESERVE THEIR NEW IDEAS (CAPTURING), SURROUND THEMSELVES WITH INTERESTING PEOPLE AND THINGS (SURROUNDING), TACKLE TOUGH PROBLEMS (CHALLENGING), AND EXPAND THEIR KNOWLEDGE (BROADENING).

MARIETTE DiCHRISTINA: Let's start by talking about what has drawn each of you to the study of creativity. What's so fascinating about it?

JOHN HOUTZ: There's so much power in a new idea taking shape and changing the way people live and act. Often the rest of us are in awe, or we are even afraid of a new idea, and sometimes our fears spur us to learn more about it. In addition to what some academics call Big Creativity or "Big C"—profound ideas that sometimes change the world—there is what we call the "little c" type of creativity: the everyday problem solving that we all do. The bottom line is that we'd all like to be more creative. We'd all like to be able to solve our problems in a better way. We don't like being frustrated. We don't like having obstacles in our path.

JULIA CAMERON: What drew me to working on my creativity was running into a couple of bumps. I had had a blessed decade in my 20s, and then when I got to my 30s I felt thwarted. I was writing movies and selling them to studios, but they weren't getting made. I needed to find a way to maintain equilibrium and optimism in the face of creative despair. I fought my despair with what I call "morning pages"—three pages of longhand writing about anything: "I don't like the way Fred talked to me at the office"; "I need to get the car checked"; "I forgot to buy kitty litter." They don't look like they have anything to do with creativity, but in fact, as we put these worries, which are sort of a daily sound track for most of us, down on the page, we are suddenly much more alert, aware, focused and available to the moment. And we begin to see that we have many creative choices. As I wrote those pages, new ideas began to walk in. Over time, I began to share the morning-pages technique with other people.

ROBERT EPSTEIN: My interest in creativity started in a peculiar way—while I was working with pigeons at Harvard in the 1970s. I was intrigued by the fact that they always did things I hadn't taught them, and I wanted to know where the new behavior was coming from. I began teaching them different things systematically and then placing them in new situations and watching new behavior emerge. There was an orderly relation between what I had taught and the new behavior, and eventually I discovered principles or laws that allowed me to predict the new behavior, literally moment to moment. Eventually I began similar research with children, and then with adult humans, and found that those laws, somewhat tweaked, were still helpful. I came to believe that the creative process in individuals is orderly and predictable at every moment in time. At some point I developed tests to see whether people have the competencies they need for expressing creativity, and then I developed games and exercises to boost creativity. I think that the fact that creativity is orderly is good news because it means we can all tap into this rich potential we all have.

CAMERON: I, too, have found the creative process to be teachable and trackable. I teach people three simple tools, and anyone using those tools has what might be called an awakening. They become much more alert; they become much more friendly

GEORGE DOYLE *Getty Images (capturing)*; ANTONY NAGELMANN *Getty Images (surrounding)*

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GETTY IMAGES (*challenging* and *broadening*)

in interacting with people—much less threatened by change.

HOUTZ: I think that some of the techniques Julia teaches are similar to the competencies Robert has uncovered. Perhaps, Robert, you might explain what those competencies are.

EPSTEIN: There are four different skill sets, or competencies, that I've found are essential for creative expression. The first and most important competency is "capturing"—preserving new ideas as they occur to you and doing so without judging them. Your morning pages, Julia, are a perfect example of a capturing technique. There are many ways to capture new ideas. Otto Loewi won a Nobel Prize for work based on an idea about cell biology that he almost failed to capture. He had the idea in his sleep, woke up and scribbled the idea on a pad but found the next morning that he couldn't read his notes or remember the idea. When the idea turned up in his dreams the following night, he used a better capturing technique: he put on his pants and went straight to his lab!

The second competency is called "challenging"—giving ourselves tough problems to solve. In tough situations, multiple behaviors compete with one another, and their interconnections create new behaviors and ideas. The third area is "broadening." The more diverse your knowledge, the more interesting the interconnections—so you can boost your creativity simply by learning interesting new things. And the last competency is "surrounding," which has to do with how you manage your physical and social environments. The more interesting and diverse the things and the people around you, the more interesting your own ideas become.

CAMERON: I've mentioned the morning pages, which sounds like your capturing, and the second technique I teach everybody—the artist "date" or "outing," I call it—is to take an adventure once a week, which probably involves both broadening and challenging. The third tool is to walk out the door for 20 minutes or so and see what happens to your thinking. When people walk, they often begin to integrate the insights and intuitions that they have had through morning pages and outings.

HOUTZ: I think if we want everyone to have a way to be more creative, we have to convey the message that they have to work at it; creativity isn't necessarily going to come naturally. And what strikes me about Julia is her high productivity. Creative people are productive. They may have lots of ideas that don't work, but the point is that they have lots of ideas. So if people want to be more creative—and to be effective problem solvers—they're going to have to be disciplined like Julia is.

THEY HAVE TO WORK AT IT; CREATIVITY ISN'T NECESSARILY GOING TO COME NATURALLY.

DiCHRISTINA: I was talking with a couple of attorneys about creativity, and one of them said, "Well, some people just have more than others, don't they?" Could we talk about why so few people express creativity?

EPSTEIN: When children are very young, they all express creativity, but by the end of the first grade,

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OBSTACLES

CREATIVITY IS SHUT DOWN IN MOST PEOPLE BY EARLY SOCIALIZATION, LEAVING IT TO "MISFITS," ACCORDING TO THE PANELISTS. BUT EVERYONE HAS ROUGHLY EQUAL POTENTIAL TO EXPRESS CREATIVITY, GIVEN THE RIGHT SKILLS.

Early Socialization

Creative "Misfits"

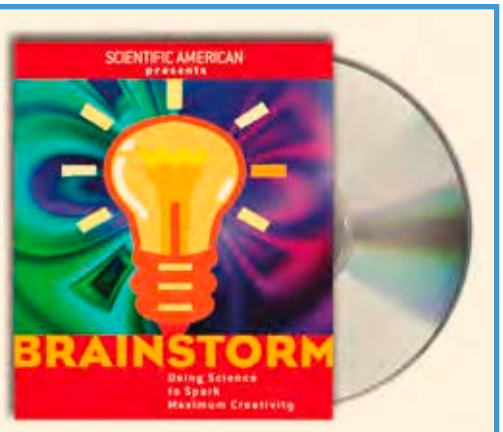
very few do so. This is because of socialization. They learn in school to stay on task and to stop daydreaming and asking silly questions. As a result, the expression of new ideas is largely shut down. We end up leaving creative expression to the misfits—the people who can't be socialized. It's a tragedy.

CAMERON: I sometimes ask people to list 10 traits they think artists have. They say things like "artists are broke," "artists are crazy," "artists are drug-addicted" and "artists are drunk." Doesn't this make you want to rush right out and become an artist? We have a mythology in America around creativity that's very, very negative. As a result, when young people tell their parents, "I'd love to be a writer," their parents respond, "Oh, darling, don't you think you might need something to fall back on?" We're also trained to believe that some people are born knowing they're artists and that they are the "real" artists, the ones who give us the Big C creativity. In other words, we have a mythology about artistry that tends to be very daunting.

HOUTZ: I think that comes from some of the studies of Big C creativity. When we look at individuals who have had a tremendous impact on some field, for whatever reason, they often turn out to be unstable or living a wild life—the misfits, as Robert said. That's very unfortunate. But there also are real obstacles for creative people. Julia, you mentioned that many of your creative projects were failing at one point. People who want to be more creative have to realize that many new ideas will at first meet great obstacles. When Robert talked about "challenge," you could read that word "challenge" in two ways. You need to challenge yourself, that's true, but you also have to realize that the world out there—society, the audience for your new idea—will perhaps need a lot of time to get used to it and may initially not want to reward you. It's important not to become discouraged. You have to keep at it!

CAMERON: When I first gave the manuscript for *The Artist's Way* to my literary agent at William Morris, she said, "Oh, Julia, *no one* is going to be interested in this." So Mark Bryan and I self-published the book by photocopying it at a little communist bookstore and selling a few copies at a little time. Emma Lively and I had worked for eight years on a musical before it got its lucky break.

You have to put up with dry spells and keep creating in the face of them.



An expanded version of this discussion—along with three other articles on creativity from *Scientific American Mind*—is available in the audiobook *Brainstorm: Using Science to Spark Maximum Creativity*. It was published in 2008 by Macmillan Audio, unabridged on CD and as a digital download. Available online wherever books are sold.

NICHOLAS PRIOR *Getty Images (socialization)*; GETTY IMAGES *(misfits)*

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EPSTEIN: When I do seminars on creativity, I teach stress-management techniques to help people cope with the rejection that goes hand in hand with creativity. You have to learn not to fear failure and even to rejoice in it. When I'm failing, I say to myself, "I'm in good company. I'm in the company of some of the most creative and productive people in the world."

HOUTZ: The creative individual thinks of failure as a new opportunity: "Okay, why did I fail? What was wrong? Let me try to do something else. Let me go forward with it."

EPSTEIN: In the laboratory, failure also produces a phenomenon called resurgence—the emergence of behaviors that used to be effective in that situation—that leads to a competition among behaviors and to new interconnections. In other words, failure actually stimulates creativity directly. It really is valuable.

CAMERON: You also need to be able to take criticism. When I write a novel, I send it out to about 10 people whom I consider to be very trusted readers. They come back to me with their criticisms, and I write another draft. Sometimes I write as many as seven drafts of a work before it goes forward into the world.

HOUTZ: There's also a stereotype that creativity is just involved in the generation of ideas. But after the ideas are generated, you then have to evaluate them, sift through them, embellish them, repair them, revise them and get them tested, which all means that the creative process is actually quite complex.

EPSTEIN: But you've got to capture now and evaluate later. A big mistake people make is to start visualizing the criticism or the feedback while they're still generating. That can shut you right down.

CAMERON: Morning pages allow you to bypass the censor because there's no wrong way to do the pages. You just keep writing. They allow you to take risks freely with your ideas.

DiCHRISTINA: There's another dynamic here, too, John, which I'm hoping you can speak to: the group dynamic of creativity. People often play different roles in the creative process, don't they?

HOUTZ: A key factor here is personality, which has been researched extensively. Some personality characteristics seem to close off the expression of new ideas. Other personality characteristics encourage that expression.

EPSTEIN: I've found that no matter what their personality, people can learn skills that boost creative output. I also doubt that there's any real difference between the little c and the Big C types of creativity. If you write enough morning pages, now and then some Big C items have a chance of creeping into the little c list—no matter what your personality.

HOUTZ: We may all have the same potential or at least the potential to be better, but if we know about our strengths and weaknesses, then we can better capitalize on our strengths, and we also know what we need to work on.

EPSTEIN: No question about that. Getting back to Mariette's question about groups, let me give you an example of an exercise I do with people that boosts group creativity. It's called "the shifting game." In this exercise, half of my teams stay together for 15 minutes to generate names for a new cola. The other teams work together for five minutes, then shift out of the group to work on the problem individually, then come together for the last five minutes. Even with all the moving around, the shifting teams produce twice as many ideas as the nonshifting ones. This happens, I think, because groups inhibit a lot of creative expression. Dominant people tend to do most of the talking, for one thing. But when people shift, everyone ends up working on the problem.

DiCHRISTINA: Don't many people believe they're not creative at all? What can you do about that?

EPSTEIN: Sometimes that's a permission issue. Many of us feel like we need permission to be creative,

THE CREATIVE INDIVIDUAL THINKS OF FAILURE AS A NEW OPPORTUNITY.

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BOOST YOUR IDEAS

TO BOOST YOUR CREATIVE OUTPUT, THINK AND BEHAVE LIKE CREATIVE PEOPLE DO: DON'T LET CRITICISM STOP YOU FROM EXPRESSING YOUR IDEAS AND DO NOT FEAR FAILURE. TAKE BREAKS AND LEARN TO USE THEM STRATEGICALLY; USE DAYDREAMS AS SOURCES OF NEW IDEAS.

Work through Criticism

Face Your Fears

maybe because of a teacher who shut us down when we were young—like my eighth grade English teacher! One thing I like to do with people is to give them permission to have a daydream. We all just close our eyes and daydream together. It can be quite a liberating experience. Virtually everyone has amazing daydreams and dreams, and those can be used to boost creative output. In fact, when you really start letting yourself go, you can end up with too many ideas. Your own output can overwhelm you, and you can get stuck!

HOUTZ: What might be some tools to help people that have the problem Robert just described?

CAMERON: I have a tool that's called "blasting through blocks." It's very simply sitting down with a piece of paper and writing down all of your angers and fears related to finishing a project. Sometimes they're very petty: I'm afraid I'll finish it, and no one will think it's any good; I'm afraid I'll finish it, and I won't think it's any good; I'm afraid I'll finish it, and it will be good, but no one will recognize that. Just getting those reservations on a sheet of paper and maybe sharing them with someone can give you the freedom to go back to work on the project.

DiCHRISTINA: How about the idea of taking breaks in order to promote creativity? There's the old adage about sleeping on something. Isn't a lot of creativity about being mindful of those times and paying attention?

EPSTEIN: Absolutely, but you can also be strategic about how you're going to use those breaks. Salvador Dalí made deliberate use of his naps to get ideas for his art, for example. While relaxing on a sofa, he'd hold a spoon out over the edge and place a plate on the floor beneath the spoon. Just as he'd drift off to sleep, his hand would relax and the spoon would fall. The sound of the spoon hitting the plate would awaken him, at which point he'd grab a pad and sketch out interesting images he might have seen in the semisleep state. Thomas Edison used a similar technique to get ideas for his inventions. And the good news here is that we all experience this state—the so-called hypnagogic state. Think about how deliberate Dalí and Edison were or about how deliberate Julia's techniques are. You don't need to leave creativity to chance.

DiCHRISTINA: I think many people make the mistake of believing that there's just no time to be creative, even to do something simple like paying attention to your thoughts and capturing them.

EPSTEIN: Well, high tech is making this easier, fortunately. These days all you have to do to capture an

THERE IS NO REASON WHY WE CAN'T DEVELOP MORE CREATIVE PROBLEM SOLVERS FROM NURSERY SCHOOL ON UP.

GETTY IMAGES (*criticism*); CAGRI ONER *Getty Images* (*fears*)

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GETTY IMAGES (*breaks*)

idea is to pick up your mobile device or memo recorder or even just to leave a message for yourself on your voice mail. You can even capture new melodies that way.

HOUTZ: This is where one's style or various personality traits might come into play. If I'm an internal person, I might enjoy the reflectivity and the quiet time and the incubation time. If I'm an external person, I might take my strength from interactions with others in a dynamic group that's giving and taking and making lots of noise.

DiCHRISTINA: How about fostering creativity and maintaining it in children? What tips do you have for educators and parents?

EPSTEIN: Well, all four of the basic creativity competencies can be taught to children. But when I've suggested to teachers that they set aside a few minutes each week for creativity training, these days they tell me that's impossible. This is an area where I see our society moving in the wrong direction—toward an obsession with raising scores on standardized tests.

CAMERON: I believe that creativity is contagious and that the best thing we can do for children is to model for them what it is like to be a creative individual.

HOUTZ: There is no legitimate reason why we can't develop more creative problem solvers from nursery school on up. There are many techniques that could be introduced into the curriculum alongside the content domains. But, as Robert said, the emphasis right now is more political than educational.

DiCHRISTINA: How might we be able to challenge our children in small ways so that we're at least keeping creativity alive at home?

EPSTEIN: One thing I like to do is make all problems open-ended. Never say, give me three ideas for this; always say, give me at least three. When tasks are open-ended, a lot more ideas are generated. I also like to use what I call "ultimate" problems with kids. Those are problems that have no real solutions. Children have great fun with problems like those. Ask them questions like "How could you get a dog to fly?" or "How could you make the sky a different color?" You can also supply your kids with idea boxes and folders—special places for putting drawings and poems and scraps of anything new. That encourages capturing on an ongoing basis and tells children that their new ideas have value.

HOUTZ: It's also important to give children permission to make decisions rather than always making decisions for them.

DiCHRISTINA: When my children have a question that I might be able to answer, I sometimes instead say, "Why don't we find out?" Then I guide them through a process of discovering the answer for themselves. They sometimes find amazing ways to get there. Are we leaving anything out?

EPSTEIN: Maybe just that there's something both humbling and exhilarating about generating a new idea. I'm looking at Julia Cameron's eyes right now, trying to imagine the extraordinary things she's put on paper that have never been seen before by anyone in human history. I believe everyone has that kind of potential. Imagine that. **M**

TEST YOUR CREATIVE COMPETENCIES

- **To get a quick fix on your creativity competencies, take the Epstein Creativity Competencies Inventory at http://MyCreativitySkills.com**
- **If you are a manager or teacher, see if you have the skills you need to stimulate creativity in other people at http://MyCreativitySkills.com/managers**

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ENGINES OF INNOVATION

MOST OF HUMANITY NOW LIVES IN A METROPOLIS. THAT SIMPLE FACT HELPS TO FUEL OUR CONTINUED SUCCESS AS A SPECIES

By Edward Glaeser

FAST FACTS

CREATIVITY HUBS

❶ Teleconferencing and virtual meetings of all stripes were supposed to spell the death of distance. Yet the city (home of more than half the human species) continues to flourish.

❷ Things seem to go better with closeness: a deal or relationship is often best sealed only with a handshake or a kiss.

❸ The interchange of ideas that occurs in the gargantuan urban swells of the developing world may help forge a pathway out of poverty.

Crime, congestion and pollution mar all cities, from Los Angeles to Mumbai. But another force trumps the drawbacks of urban living: cities bring opportunities for wealth and for the creative inspiration that can result only from face-to-face contact with others. In fact, the crush of people living in close quarters fosters the kind of collaborative creativity that has produced some of humanity's best ideas, including the industrial revolution and the digital age. In the years ahead such collaborations can be expected to help solve the world's most pressing problems—poverty, energy shortages, climate change—and to promote fundamental political transitions.

Why do cities bring out the best in us? Technology lets us hold virtual meetings, and the Internet keeps us in touch 24/7, but neither can be a substitute for the social cues—such as a facial expression signaling comprehension or confusion—shared when people meet in an office, bar or gym. Cities deliver the random exchanges of insight that generate new ideas for solving the most intransigent problems. [For more on this mechanism, see "Bigger Cities Do More with Less," by Luís M. A. Bettencourt and Geoffrey B. West, on page 106.] Young workers, whether they are on Wall Street or in Google's New York City offices, succeed by picking up unexpected bits of knowledge from the successes and failures of those around them. It has always been so.

Think of the chain of brilliance that spread throughout the towns of 18th-century England and brought us the industrial revolution. The crucial technology for spinning with rollers started

Golden Prosperity Building, or the Jin Mao Tower, lords it over Shanghai's more than 23 million residents.

JOSEF HOFLEHNER *Gallery Stock*

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with Lewis Paul and John Wyatt in Birmingham, passed to John Kay and Thomas Highs, and then ended in the hands of Richard Arkwright, thanks to a discussion over a few drinks outside of Manchester. By supercharging the flow of ideas, cities foster economic prosperity, innovation, better health—and even new ways to govern ourselves.

A Superhighway of Ideas

The constant interchange of ideas has helped cities throughout the developing world find a pathway out of poverty and into prosperity. Average incomes reach a level more than five times higher in countries that are mostly urbanized compared with those in which most of the population stays in the countryside. Across districts in India, mean individual earnings increase by about 20 percent as density doubles, even when individual age and education are constant.

As hubs of global commerce, cities also facilitate integration with the world economy. People in developing nations can become prosperous if they can sell their time—transformed into goods and services—to wealthy markets. In essence, cities connect poor countries with rich markets.

One example is telling. N. R. Narayana Murthy, one of the billionaire founders of Indian software giant Infosys, graduated in the 1960s from the University of Mysore and the Indian Institute of Technology Kanpur, but in those years an Indian engineering degree could not guarantee a high income. Murthy started working at Patni Computer Systems (later bought by iGate), whose founders had lived in the U.S. and understood how to work with the American appetite for software. The founders took their knowledge back to India and, joined by Murthy, set up a back-office operation in Pune to serve U.S. companies, thereby linking Indian talent and American markets.

In 1981 they started their own software company and netted their first U.S. client in 1982. A year later they moved to Bangalore to work with a German spark-plug producer that wanted Infosys nearby. About 30 years on, Infosys is a flat-world phenomenon that has made billions of dollars for its founders and has trained thousands of Indians in Bangalore, helping them to become more prosperous by selling their engineering talents worldwide. That success has also rippled through the food chain in Bangalore to the service providers in local restaurants and taxis, which translates into jobs for thousands of other Indians.

Another small-world sensation emerged not far from Hong Kong. Shenzhen had little industry before 1980, when the People's Republic of China made Shenzhen its first special economic zone intended as a magnet for foreign investment in manufacturing. Tax breaks and exemptions from trade regulations encouraged such investment. Manufacturers were drawn by the opportunity to make goods with inexpensive Chinese labor; workers came because factory jobs offered far more economic opportunity than life in rural China. Pepsi was the first American company to move into Shenzhen in 1982, bottling soda for Hong Kong consumers at a fraction of Hong Kong wages. Other international companies followed, making toys, handbags, sneakers and, ultimately, more sophisticated products. Today the area has more than 10 million people, and the McKinsey Global Institute, McKinsey & Company's economic and research arm, predicts that it will be the world's 10th-largest urban economy by 2025.

Healthy Ideas

Cities can breed health as well as wealth. Life expectancy in New York is now more than two years higher than the national average. It is not entirely clear why older New Yorkers are healthier. Some people credit walking; others talk about social connections made possible by density. But among younger people, the reasons are no mystery. Motor vehicle accidents and suicides are two primary killers of people younger than 35 years, and both are far less common in cities. In New York City the death rate from motor vehicle accidents is more than 70 percent lower than in the country as a whole. Taking the subway after a few drinks is just a lot safer than driving drunk.

Cities can also make humankind healthier by producing knowledge. John Snow, a founder of epidemiology, had his great breakthrough in 19th-century London, when the city itself provided the information he needed to understand cholera. By studying the urban map of a cholera outbreak, he was able to connect the disease to a water pump and grasp the connection between polluted water and infection. More recently, early breakthroughs in AIDS occurred when Parisian researchers perceived the pattern of infection within that city. The knowledge that cities can provide is often the best weapon against disease.

The cities of the developing world are not yet healthy, in part because their governments have been unable to provide the basic infrastructure that cities need. Still, cities themselves may supply their own solutions. Often they are where the seeds of revolution

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against bad government sprout, and living contiguously facilitates the coordination that enables citizens to create reform movements that rise up and oust dictators. Urban uprisings do not always end in stable democracies, but most stable democracies benefited at some time from an urban uprising.

Europe's first modern republic—the Netherlands—had its roots in centuries of popular rebellions in the wool-making towns of Flanders, such as Brugge. In the central square of Brugge stands a statue of a weaver and a butcher, urban artisans, who are celebrated not for their crafts but because they helped to organize their fellow guild members in the fight against French royal rule. On May 18, 1302, they organized an urban insurrection, now called the Brugge Matins, and massacred the French knights occupying their town. Almost two months later Brugge's disciplined artisans and their allies demolished the flower of French chivalry at the Battle of the Golden Spurs.

These victories did not produce a republican government for centuries, until the fire of the Reformation, which had spread across the cities of northern Europe, added an extra religious reason to rebel. In 1556 the Low Countries had passed into the hands of the Spanish Hapsburgs, who attempted to tax and regulate these urbanites. Cities once again managed to coordinate action: first, an orgy of iconoclasm and then full-fledged revolt. The uprising took decades, and Flanders itself remained part of Spain, but the end result was an urban republic—the Netherlands—that became the center of a global empire of trade and conquest and a model for many republics to come.

The U.S.'s own uprising had its start in the dense corridors of 18th-century Boston, which connected revolutionaries-to-be such as Samuel Adams and John Hancock. Hancock had a commercial interest in getting crowds to agitate against British mercantilist policies; Adams knew how to conjure a crowd. Together they and their Bostonian allies—John Adams, Paul Revere and many others—became the nucleus of a fight for popular sovereignty.

The Facebook Revolution

The ability of cities to spread ideas of freedom and to coordinate mass action has led to countless revolts since then, from Paris in 1789 to St. Petersburg, Russia, in 1917 to Cairo in 2011. The toppling of former Egyptian president Hosni Mubarak has been called a Facebook revolution, but he would not have left if people had just blocked him from their Facebook pages. They needed to take to Tahrir Square.

Humankind continues to confront enormous challenges, from endemic poverty to global warming, but the track record of our urban species makes me optimistic. I have enormous confidence in the ability of *Homo sapiens* to work miracles when people cooperate. Our greatest gift is our ability to learn from one another, to work together, to solve problems by leveraging our collective intelligence.

The new electronic media can facilitate that collaborative process, but so does the face-to-face contact that is made possible by the physical proximity afforded by cities. Cities have been solving our species' principal challenges for millennia, and they are likely to keep on doing so for centuries to come. **M**

PHILIP SIDEN *Gallery Stock*

Urban centers worldwide attract elite workforces whose collaborative creativity generates some of our best ideas.

MORE TO EXPLORE

- **The Rise of the Skilled City.** Edward L. Glaeser and Albert Saiz in Federal Reserve Bank of Philadelphia Working Papers, 2003. **http://ideas.repec.org/p/fip/fedpwp/04-2.html**
- **Triumph of the City: How Our Greatest Invention Makes Us Richer, Smarter, Greener, Healthier and Happier.** Edward Glaeser. Penguin Press, 2011.
- A collection of papers by Glaeser on his Harvard University Web site: **http://scholar.harvard.edu/glaeser/publications**
- Read a chapter from Glaeser's book, *Triumph of the City:* **www.scientificamerican.com/article/glaeser-triumph-of-the-city-excerpt**

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BIGGER CITIES DO MORE WITH LESS

SCIENCE REVEALS WHY CITIES BECOME MORE CREATIVE AND EFFICIENT AS THEY GROW

By Luís M. A. Bettencourt and Geoffrey B. West

For centuries people have painted cities as unnatural human conglomerations, blighted by pathologies such as public health crises, aggression and exorbitant costs of living. Why, then, do people throughout the world keep leaving the countryside for the town? Research that has been forming a multidisciplinary science of cities is beginning to reveal the answer: cities concentrate, accelerate, and diversify social and economic activity.

The numbers show that urban dwellers produce more inventions and create more opportunities for economic growth. Often large cities are also the greenest places on the planet because people living in denser habitats typically have smaller energy footprints, require less infrastructure and consume less of the world's resources per capita. Compared with suburban or rural areas, cities do more with less. And the bigger cities get, the more productive and efficient they tend to become.

The Power of Population

This new, more quantitative science of cities is becoming possible because of the increasing availability of information—official statistics as well as novel measures of human and social activity—on cities and metropolitan areas worldwide.

By sifting through this flood of data, covering thousands of cities around the world, we have unveiled several mathematical "laws" that explain how concentrating people in one place affects economic activity, return on infrastructure investment and social vitality. Despite the rich diversity of metropolitan regions across the U.S., China, Brazil and other nations, we found a remarkable universality in the way that socioeconomic characteristics increase with a city's population. For example, if the population of a city is doubled, whether from 40,000 to 80,000 or from four million to eight million, we systematically see an average increase of around 15 percent in measures such as wages and patents produced per capita. If eight million people all live in one city, each person's economic output will typically be about 15 percent greater than if the same eight million people lived in two cities of half the size. We call this effect "superlinear scaling": the socioeconomic properties of cities increase faster than a direct (or linear) relation to their population would predict [*see illustration on opposite page*].

The data also reveal that cities' use of resources follows a similar, though inverted, law. When the size of a city doubles, its material infrastructure—anything from the number of gas stations to the total length of its pipes, roads or electrical wires—does not. Instead these quantities rise more slowly than population size: a city of eight million typically needs 15 percent less of the same infrastructure per capita than do two cities of four million each. This pattern is referred to as sublinear scaling. On average, the bigger the city, the more efficient its use of infrastructure, leading to important savings in materials, energy and emissions.

Our findings also show that these patterns of increased productivity and decreased costs hold true across nations with very different levels of development, technology and wealth. Although we have much more information for cities in richer parts of the world, we are beginning to obtain good data from rapidly developing countries as well, and they seem to fit the same mold.

Although urban superlinear scaling prevails around the globe, actual cities deviate to varying degrees from the roughly 15 percent enhancements per capita that come with size. Detailed data covering 40 years show, for example, that San Francisco and Boston are richer than their size would indicate, whereas Phoenix and Riverside, Calif., are somewhat poorer. Curiously, these deviations persist for decades: cities tend to stay remarkably close to their overperforming or underperforming histories. For example, cities that have attempted to become the "next Silicon Valley" have often had disappointing results. Our research suggests that certain intangible qualities of social dynamics—more than the development of material infrastructure—hold the key to generating virtuous cycles of innovation and creation of wealth. These processes, such as the development of a spirit of local entrepreneurship, a reputation for cutting-edge novelty, and a culture of excellence and competitiveness, are difficult to design through policy because they rely on the dynamics of a city's social fabric across many dimensions.

What we can say with certainty, however, is that increased population promotes more intense and frequent social interac-

FAST FACTS

DENSITY DRIVES CREATIVITY

❶ Recent research shows that the bigger a city gets, the more innovative and efficient its residents become.

❷ Increased population promotes more intense and frequent social interactions, and cities with a culture of entrepreneurship and excellence are most successful at capitalizing on these interactions.

❸ Although urban expansion does not come without growing pains, many of civilization's greatest inventions, such as plumbing and electricity, have arisen from the need to accommodate rapidly swelling urban populations.

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tions, occurrences that correlate with higher rates of productivity and innovation, as well as economic pressures that weed out inefficiencies. In a city with high rents, only activities that add substantial value can be profitable. These economic pressures push urbanites to come up with new forms of organizations, products and services. In turn, higher profitability, excellence and choice tend to attract more talent to the city, pushing rents higher still, fueling the need to find yet more productive activities. This feedback mechanism, in a nutshell, is the principal reason cities accelerate innovation.

Denser but Greener

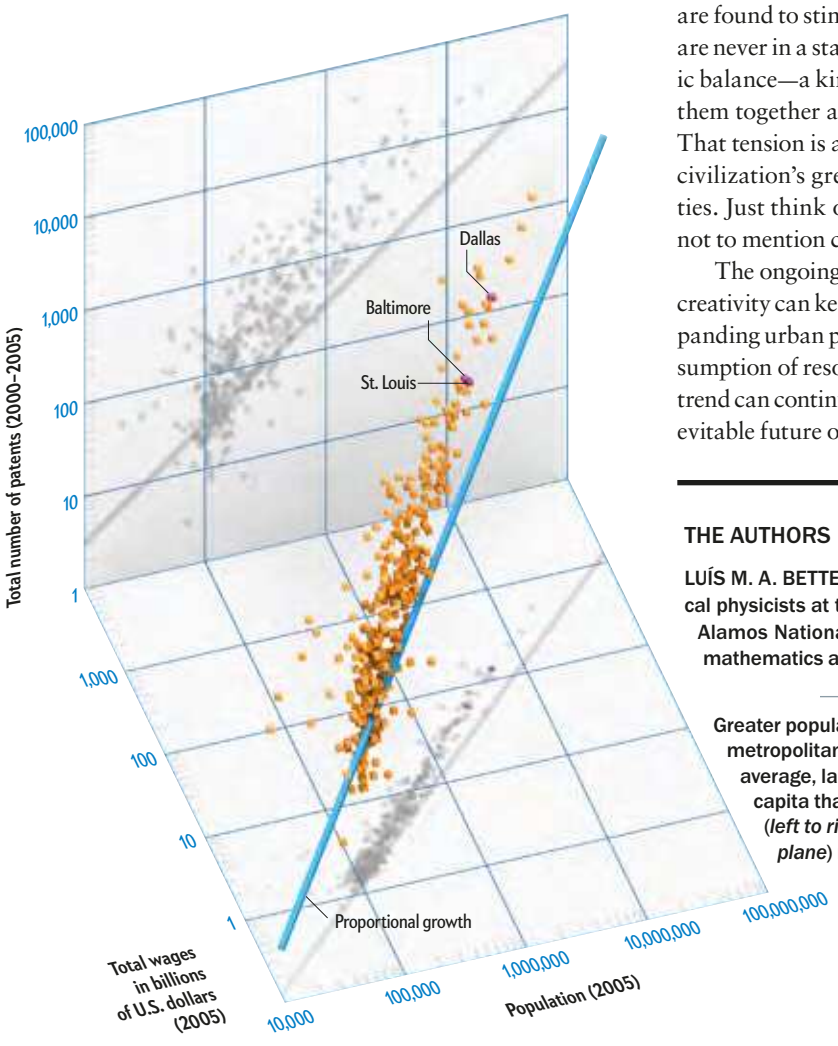
Although cities create economic opportunities in rich and poor countries alike, people living in wealthier areas find it difficult to imagine why so many inhabitants of poor countries are attracted to cities such as Nairobi, Lagos or Mumbai, where newcomers often end up in slums marked by pollution, crime and disease. These appalling conditions, however, should remind residents in developed nations of their own urban past. When Charles Dickens wrote about life in mid-1800s London or when Jacob Riis photographed the Bowery district of New York City's Lower East Side in the late 1800s, each was reporting similar circumstances. These cities grew explosively during the 19th century—sevenfold for London and almost 60-fold for New York. Well-run modern cities have demonstrated that pervasive ills are not inescapable. The problems result primarily from nonexistent or poor planning and a lack of good governance. The development of these organizational traits may, in fact, be the most important and long-lasting effect of urbanization because it paves the way for socioeconomic development at the national level.

Some benefits besides wealth and innovation come about even when not legislated. One notable example is the impact of cities on the environment. Quality data are only now beginning to emerge, but we can already see that the largest U.S. cities have the lowest carbon dioxide emissions *per capita*. This gain is mostly an unplanned by-product of people living at greater densities because the bulk of the savings comes from energy-efficient public transportation and simple walking instead of driving.

Environmental efficiency becomes more challenging for developing nations such as India or China, where much urban infrastructure still needs to be built. Still, urbanization may be the most sustainable solution to our planet's environmental challenges.

Unbridled growth can nonetheless create crises that, in the extreme, could cause a city to collapse unless major innovations are found to stimulate new cycles of growth. In this sense, cities are never in a state of stable equilibrium. They exist in a dynamic balance—a kind of tug-of-war—between the forces that bind them together and those that can potentially tear them apart. That tension is another reason cities drive innovation: many of civilization's greatest inventions have come from dire necessities. Just think of plumbing, electricity and even democracy—not to mention coffee shops.

The ongoing challenge for urban growth is whether human creativity can keep innovating sufficiently fast to sustain ever expanding urban populations while decreasing our per capita consumption of resources and impact on the planet. As long as this trend can continue, cities will grow ever larger and will be the inevitable future of a more creative and prosperous humanity. **M**



GRAPHIC BY BRYAN CHRISTIE; SOURCES: U.S. BUREAU OF ECONOMIC ANALYSIS (*wages of U.S. metropolitan areas*); U.S. PATENT AND TRADEMARK OFFICE (*data on patents filed between 2000–2005 for U.S. metropolitan areas*); COURTESY OF DEBORAH STRUMSKY AND JOSÉ LOBO

Greater population means greater dividends. Studies comparing metropolitan areas (orange cubes are U.S. data) show that, on average, larger cities produce more wealth and innovation per capita than smaller ones do. As city population increases (*left to right*), wages (*horizontal plane*) and patents (*vertical plane*) rise even faster. If these indicators grew only at the same pace as population (direct proportionality), the cubes would align closer to the blue line. A typical example: the St. Louis and Baltimore areas, with about 2.5 million inhabitants each, generate combined wages of $118 billion, yet Dallas, at five million people, has $130 billion in wages.

THE AUTHORS

LUÍS M. A. BETTENCOURT and GEOFFREY B. WEST are both theoretical physicists at the Santa Fe Institute. West is a senior fellow at Los Alamos National Laboratory. They have introduced methods from mathematics and physics into biology and the social sciences.

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SWITCHING ON CREATIVITY

THE EXTRAORDINARY ABILITIES OF SAVANTS HAVE INSPIRED A BRAIN-STIMULATION TECHNIQUE FOR ENABLING CREATIVE INSIGHT

By Allan W. Snyder, Sophie Ellwood and Richard P. Chi
Photoillustration by William Duke

A great idea comes all of a sudden. In the depths of the mind, networks of brain cells perform a sublime symphony, and a twinkle of insight pops into consciousness. Unexpected as they are, these lightbulb moments seem impossible to orchestrate. Recent studies suggest otherwise. By freeing the mind of some of its inhibitions, we might improve creative problem solving.

The human brain constantly filters thoughts and feelings. Only a small fraction of the stimuli impressed on us by our environment ascends to the level of conscious awareness. Prior learning enforces mental shortcuts that determine which sensations are deemed worthy of our attention. Our laboratory has investigated whether we can weaken these biases and boost openness to new ideas by temporarily diminishing the neural activity in specific brain areas.

The inspiration for this approach came from individuals with brain impairment. People with savant syndrome—those rare individuals who possess uncanny skill in specific, circumscribed domains while struggling in others—appear to show a pattern of left-hemisphere dysfunction with a tendency for right-hemisphere dominance. We theorize this arrangement renders their mental filters less powerful than those in normal, healthy adults.

Genius, rare as it is, must demand a qualitatively different view of the world than what most of us experience. Austrian physician Hans Asperger, whose name is associated with the eponymous condition formerly used to describe mild forms of autism, suggested that "a dash of autism" might set brilliant minds apart. We have investigated this hypothesis by using weak electric current to modulate brain activity in healthy people in our lab. The effects fade in an hour, preserving normal cognition. This method of brain stimulation is safe and portable, suggesting the possibility of a device—a "creativity cap"—that anyone might use to spur creativity on demand.

Limited by Mindsets

The brain does not passively receive information. It actively interprets what we think of as our raw experience in light of past knowledge. Two people looking at the same cloud formation, for example, may form completely different impressions of the patterns in the vapor: the ultrasound technician may see a dis-

FAST FACTS
OPENING THE MIND

❶ People with savant syndrome, who possess great skill in specific areas, seem to have a more literal, less filtered cognitive style than most people.

❷ A savant may have dysfunction in the normally dominant left hemisphere of the brain, which the right hemisphere compensates for.

❸ Using noninvasive brain stimulation, scientists are attempting to induce this pattern of brain activity, so as to produce a less filtered cognitive style and to access a different way of looking at a given problem.

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Stephen Wiltshire, an artist with autism, can produce faithful recreations of intricate scenes after viewing them for only a short time. Such unusual skills may offer clues to inspiring creativity more broadly.

eased gallbladder, whereas the portrait painter may observe a dignified face.

Mindsets are crucial. They allow us to predict likely outcomes based on incomplete information and to negotiate day-to-day activities efficiently. Without them, we would see the world naively, unable to distinguish between important and irrelevant details. This cognitive architecture also leaves us susceptible to errors, however, including illusions, false memories and prejudice. Mindsets make us less receptive, perhaps even resistant, to novel interpretations. Once a mindset is formed, we lose conscious access to the stimuli that make up a thought. For example, read this passage:

A bird in the
hand is worth
two in the
the bush

Many readers fail to spot the double "the." The late neurologist Oliver Sacks read the sentence in our lab many times without detecting it. Humans are instinctively conceptual, not literal, thinkers.

We argue that creative insight requires two cognitive styles—one approach is mindset-driven, and one grants us an unfiltered experience of the world around us. We would like to access perceptual details usually hidden from conscious awareness, potentially unlocking the genius within us all.

A Dash of Autism

A clue for achieving this goal comes from savants, most of whom fall on the autism spectrum. Savant skills sometimes appear in early childhood; other times they emerge after damage to the brain. These abilities tend to call on a less conceptual, more literal way of thinking. For example, when the teacher of a boy with infantile autism asked him to recall the ending of a particular book, he recited the last page verbatim but showed no comprehension of its gist. Although in the extreme this cognitive style is a setback in daily life, it can also confer a range of advantages, including superior drawing abilities and a reduced susceptibility to illusions and false memories.

Stephen Wiltshire, for instance, is a British artist with autism who has been able to produce spectacularly detailed drawings from a young age. He can draw with photographic realism, in minute detail, whereas most adults tend to draw according to their internal schemas, producing crude but meaningful caricatures. In our view, Wilt-

THE ABRUPT EMERGENCE OF AUTISTICLIKE COGNITIVE ABILITIES IN ACQUIRED SAVANT SYNDROME POINTS TO THE POSSIBILITY THAT THESE SKILLS ARE LATENT IN US ALL BUT ARE BEYOND CONSCIOUS ACCESS.

DAN KITWOOD *Getty Images*

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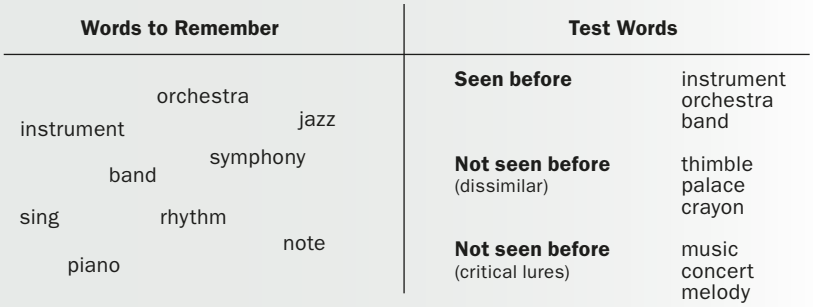
shire and others like him have privileged access to more raw, less processed information about the world. This literal cognitive style appears to allow a person to work bottom up, from the parts to the whole.

A number of studies suggest that savants have some form of left-hemisphere dysfunction, together with right-hemisphere facilitation. (Typically damage to one hemisphere of the brain incites compensatory activity in the other half.) This characteristic can be observed from early childhood or after an injury, stroke or dementia damages the left hemisphere. Some of these impairments occur in a brain area of particular interest to us, the left anterior temporal lobe. This region is known to be involved in semantic memory, which includes the ability to categorize or combine concepts—in essence, filtering thoughts. Neurologist Bruce Miller of the University of California, San Francisco, for example, has documented multiple cases of dementia in which degeneration in the left anterior temporal lobe is associated with the sudden emergence of savantlike literal skills. Some of his subjects began producing realistic art—meticulous copies of scenes lacking abstract or symbolic features—without training.

Acquired savant skills are not restricted to drawing. T. L. Brink, then at the Palo Alto School of Professional Psychology, described the case of Mr. Z, who as a nine-year-old child suffered a gunshot wound to the left temporal lobe. He lost the ability to read and write but suddenly gained extraordinary mechanical skills; for example, he discovered he could dismantle and reassemble multigear bicycles without instruction. Another case is Orlando Serrell, whom we have studied, who was hit on the left side of his head with a baseball when he was 10. He has exhibited savant skills in calendar calculation—the ability to swiftly discern the day of the week that a given date falls on—and in literal recall of the weather every day since his accident. The abrupt emergence of autisticlike cognitive abilities in acquired savant syndrome points to the possibility that these skills are latent in us all but are beyond conscious access.

A BOOST FROM BRAIN STIMULATION



In one experiment, participants were shown a list of words. Later they were shown another list and asked which words they had seen earlier. The use of transcranial magnetic brain stimulation improved subjects' ability to distinguish between words they had already seen and closely related but absent words—the critical lures.

Finding Our Inner Savant

Intriguingly, recent evidence suggests we need not wound ourselves to access this altered cognitive state. We can quiet neuronal activity in the left hemisphere for brief periods using well-accepted forms of noninvasive brain stimulation. Many studies have shown that such stimulation can temporarily either inhibit or enhance neuronal activity in targeted areas. These techniques are now being explored for numerous applications, including the treatment of depression, eating disorders and speech impairments, among many others.

We started by investigating transcranial magnetic stimulation, a method in which a powerful magnet, positioned over a well-defined part of the brain, interferes with the normal flow of current in nearby neurons. The magnetic field disrupts the firing patterns of established networks of brain cells, whose connections were forged through a lifetime of learning. By targeting specific areas of the brain involved in synthesizing high-level concepts, we hope to reduce the influence of prior knowledge. In published studies so far, we have been able to enhance several skills in ordinary humans, including drawing, proofreading, numerosity estimation (counting the number of items, such as matchsticks, in a group) and verbal memory. The device needed to deliver this kind of stimulation is bulky and expensive, however.

A more promising approach is called transcranial direct-current stimulation (tDCS). This method is a safe, simple way to alter the likelihood that networks of neurons near the surface of the brain will fire. In our setup, a weak electric current passes between two electrodes, a cathode and an anode, placed on the scalp over the left and right anterior temporal lobes, just above the ears. At the cathode, the underlying neurons become less likely to fire, and vice versa for the anode. This dose of current alters the behavior of neurons for about an hour, a temporary window during which recipients can access a different cognitive style.

THE AUTHORS

ALLAN W. SNYDER is a physicist and neurobiologist at the University of Sydney, where he founded the Center for the Mind, and is a fellow of the Royal Society. SOPHIE ELLWOOD is currently at the University of Sydney. RICHARD P. CHI earned his Ph.D. at the Center for the Mind and Sydney Medical School and was a research fellow at the Laboratory of Neuromodulation at Harvard Medical School.

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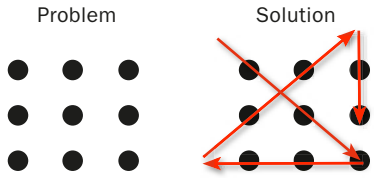
Boosting Brilliance

In a 2011 study using our apparatus, we asked 60 right-handed participants to solve a series of matchstick arithmetic "insight" problems. An erroneous arithmetic statement, spelled out in Roman numerals using matchsticks, must be corrected by moving one matchstick.

Participants were first given 27 problems that all involved one type of solution, namely changing an "X" to a "V." The goal was to prime the subjects to become fixed in one way of solving problems. Once people have learned to solve a problem, past research has shown, they often struggle to generate solutions using a different approach. As economist John Maynard Keynes put it, "the difficulty lies not in grasping the new ideas but rather in escaping from the old ones."



Solving the nine-dots problem (*shown here*) requires letting go of the idea that the dots form the border of an imaginary grid.

The participants then received five minutes of DC stimulation. For one third of the group, we placed the cathode on the left anterior temporal lobe (to decrease the likelihood of neurons firing in that area) and the anode on the right anterior temporal lobe (to boost the chances of neuronal activity there). For another 20 participants, we switched the cathode and the anode. The final third received sham stimulation.

Next the subjects had six minutes to solve another problem. This task required a different kind of solution. As we had expected, many people were stuck. Yet 60 percent of those in the group that received stimulation according to our parameters solved the problem. Only 20 percent of those in the placebo group solved the new problem, and reversing the direction of stimulation did not have a significant effect on performance.

We did a follow-up study to ensure that our results were not a fluke. This time we used a notoriously difficult task—the classic nine-dots problem. The goal is to connect all nine dots with four straight lines, drawn without lifting pen from paper or retracing a line. A century of research has established that in the lab setting, at most 5 percent of participants manage to crack it, and very likely fewer manage to do so. Most people fail to decipher it even with hints and plenty of time. The reason is that the problem activates seemingly relevant prior knowledge that obstructs the solution. We tend to see the dots as a square, with rigid boundaries. Solving the puzzle requires the examinee to do away with false constraints and view the problem in a new light.

Subjects were given three opportunities to solve the nine-dots problem: they tackled it for three minutes before brain stimulation, three minutes during stimulation and three minutes immediately after the current was turned off. None of our participants solved the problem before stimulation or in the sham condition. Yet 14 out of 33 individuals did so as a result of receiving stimulation at the anterior temporal lobes according to our protocol. We calculated that the probability that this fraction of people could solve it by chance is less than one in a billion.

Many questions remain unanswered, of course. The precise effects of tDCS inside the brain are not completely understood, so mechanisms other than the ones we theorize might explain our results. The outcome of DC stimulation also depends on various factors, including which hemisphere is dominant and what the recipient's mental state is. Furthermore, problems are often difficult in multiple ways, and tDCS may only help with overcoming one of the many bottlenecks.

DIRECT CURRENT ALTERS THE BEHAVIOR OF NEARBY NEURONS FOR ABOUT AN HOUR, DURING WHICH TIME WE CAN ACCESS A DIFFERENT COGNITIVE STYLE.

We want to emphasize that our approach aims not to enhance an existing ability but to reduce the limitations of prior knowledge. This type of cognitive enhancement is qualitatively different from what scientists normally seek to develop. Ultimately our goal is to develop a device that circumvents mental blocks to creativity. Having at our disposal two approaches—the usual way of thinking and the autistic focus on detail—could facilitate the ability to make truly novel connections, which is the essence of creative genius. M

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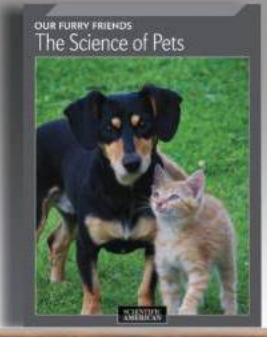

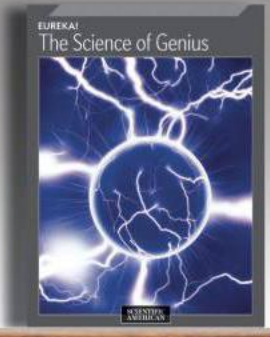

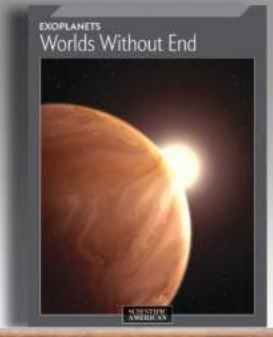

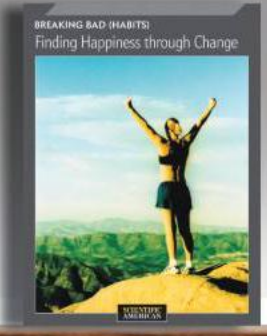

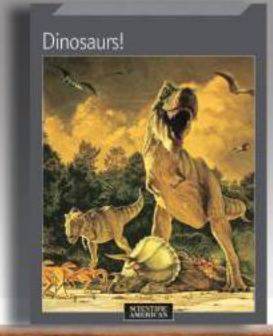

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